ILLUMINATING ENGINEERING

APRIL 1951

Psychological Aspects of Color and Illumination
Muscle Action and Visual Tasks in Industry
Uniformity in Highway Illumination Design
A Simple Daylighting Survey Technique
Lighting an Engineering Building
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Daylight in Classrooms

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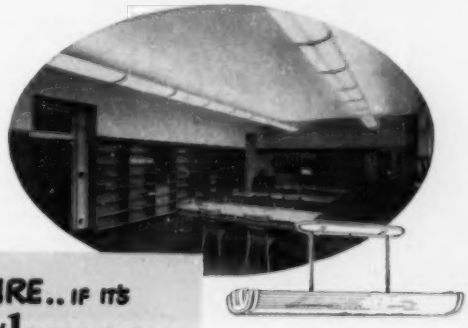

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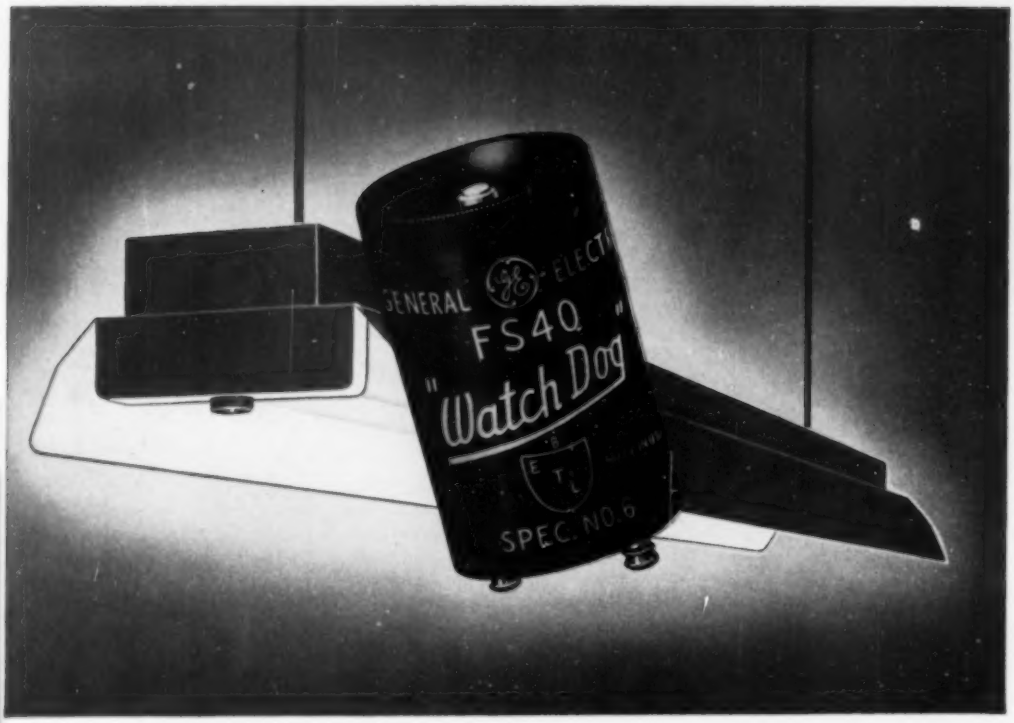

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Dual Purpose Lighting in New Wisconsin Engineering Building

By LUDVIG C. LARSON

In the dynamo laboratories in the new engineering building a practical means of high-quality industrial lighting is shown. The semi-direct luminaires have 45 x 45 degree shielding. Light from the luminous sides and through the perforated top-plate reflectors creates a luminous background for the lighting units. Although there are some reflections of lighting units in mirrored instrument faces, neither students nor faculty have considered them objectionable. The reduced contrast resulting from the upward light of this system is undoubtedly an important factor in this situation. Luminaires contain two 8-foot T-12 lamps, providing 45 footcandles in service at the 34-inch height of instrument tables. Vertical illumination varies from 20 to 16 footcandles from top to bottom of the panel boards.

THE first unit of the new Engineering Building at the University of Wisconsin is occupied by the Department of Electrical Engineering and the Department of Mechanics. Careful planning went into not only the general design of the structure, but was carried through to the many small details. The result is a practical, effective and efficient plant that facilitates the educational and research activities of these engineering departments.

The lighting for the building was selected to meet the general and specific requirements of such

Author: Professor of Electrical Engineering, University of Wisconsin, and Director of the state's Electrical Standards Laboratory, Madison, Wisconsin.

The simple luminous elements of plastic louver sections fit into the design of the entrance (left). De luxe warm-white lamps in the lobby produce about 40 footcandles, making transition to and from the building comfortable by day. At night the entrance attracts attention without being glaring. De luxe cool white lamps are used in the vestibule.

First floor corridors (right) are lighted with recessed two-lamp troffers. Six 11-inch by 12-inch curved lens plates enclose the 72-inch units. Suspended corridor ceilings have "cat-walks" for access to many service supply systems. Space between corridor and classroom walls will permit ready expansion of such facilities. Display cases are lighted by recessed soffit units. Surface-type units are used in upper-floor corridors.

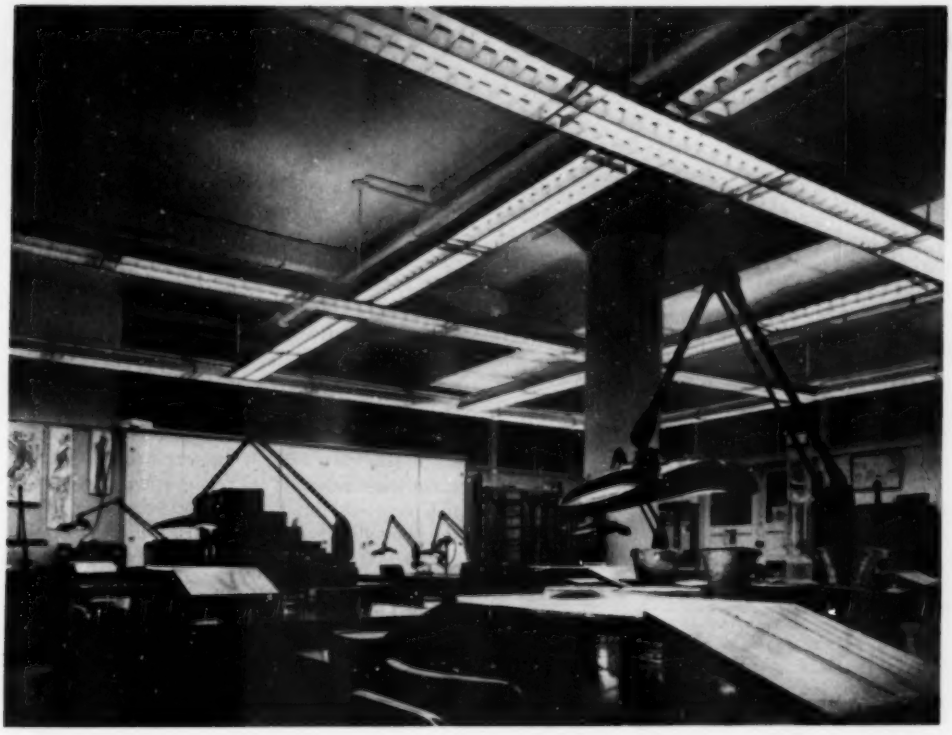
In walls receiving direct sunlight, directional glass blocks are employed in combination with clear-glass vision strips (left). Laboratory furniture is made of selected maple in natural finish. Asphalt tile floors have a reflectance of about 20 per cent. Eight-foot, two-lamp units are suspended 18 inches to clear ducts housing eight to ten different types of power supply to each laboratory.

a diversified organization. It was designed to give students and faculty comfortable and pleasant working-living conditions. To this end, light but colorful finishes and materials have been used throughout.

The building also provides a large lighting demonstration laboratory, employing luminaires by many manufacturers to present a variety of lighting techniques. Architects were Foeller, Schober, Berners, Safford and Jahn, Green Bay, Wisconsin.

Surface-mounted aluminum units in this lecture room (right) have 40 x 40 degree shielding. Gimbel-mounted projector lamps (not lighted in photograph) are employed at the end of each row to increase chalkboard illumination and to highlight lecture demonstrations.

A corner of the Electrical Standards Laboratory (left) is operated for the State of Wisconsin. This and the Cement Research Laboratory are air-conditioned. The acoustically-treated furred ceiling and the shielded luminaires are in keeping with the needs of this precision measurements laboratory. Here much work is done in testing electrical products for safety in cooperation with the state industrial commission.



High Level Lighting for Seed Inspection

ILLUMINATION levels of a high order were required for the industrial task shown above—the careful inspection of hundreds of tiny seeds.

Supplementary units which are virtually portable lighted magnifiers over each inspection area provide levels in the 300-footcandle range, supplementing the general lighting, which of itself is in the order of 100 footcandles.

The room is 33 feet by 33 feet, with an 11-foot ceiling. High level general lighting is provided by continuous rows of two-lamp, semi-direct luminaires mounted eight feet six inches from the floor to the bottom of the unit on 24-inch suspension. Spacings are nine feet, and nine feet six inches. Two standard cool T-12 40-watt fluorescent lamps are employed in each unit. The ceiling is white with a trace of pink, giving 73 per cent reflectance; walls are flat white (83 per cent reflectance); desks are oak (30 per cent); floor is a mottled cream (43 per cent reflectance). Levels of 100 footcandles general lighting are obtained, using a 75 per cent maintenance factor.

The seed inspection desks are each equipped with a supplemental lighting device, which is in reality a portable lighted magnifier employing a large size moderate magnification lens. Each of the portable units contains two six-watt fluorescent lamps. Illumination levels over the desks are approximately 300 footcandles, which in conjunction with the magnifying lens, gives excellent visibility of the small seeds being inspected.

The installation is at the plant of Northrup King and Company, Minneapolis, Minnesota.

Illustration and data were furnished by E. A. Linsday, General Electric Company, Nela Park, Cleveland, Ohio.

A Simple Daylighting Survey Technique

By R. W. McKINLEY

CAREFUL fenestration planning and material application will provide effective brightness control and at the same time ensure good daylight utilization in buildings of all types in almost any location.

To compare and evaluate the effectiveness of various daylight control devices such as light-diffusing and light-directing glass blocks, roller shades, draw drapes, venetian blinds and exterior louvers, a different survey technique is required from that ordinarily used in checking electric lighting installations.

It is usually desirable, for example, to compare performance under each of three different exterior conditions:

1. Overcast Day
2. Clear Day — No Sun on Fenestration
3. Clear Day — Sun on Fenestration

The practical daylight brightness control problem in any interior varies with the azimuth and altitude of sun and is influenced by the reflectance of metal roofs, snow cover, nearby buildings, and natural obstacles. On elevations not exposed to direct sunlight, cloud brightness (often as high as 5000 footlamberts) must be controlled.

Because of these variables, a complete report on fenestration performance should include, in addition to specific illumination and brightness measurements, some statement regarding performance in winter, summer, spring, and fall.

Interior illumination and brightness may be considered to vary directly in proportion to the exterior illumination of the fenestration, the fenestration area and interior surface reflectance. Thus, the more light outside, the larger the fenestration area and the higher the interior reflectance, the higher the levels will be inside.

The following daylighting survey technique provides means for correcting for the important variables. Data obtained in this manner will provide reliable means for checking design predictions and comparing different types of fenestration.

Author: Development Engineer, Pittsburgh Corning Corp., Pittsburgh, Pa.

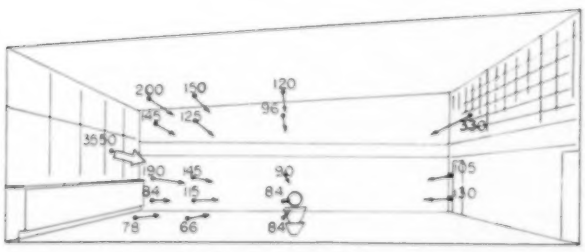
Results of a Daylighting Survey in a West Coast College Classroom

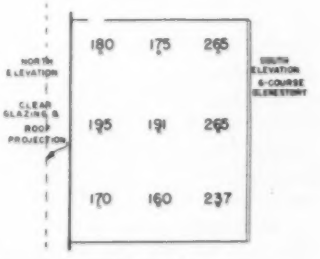
Room Dimensions—40′ 1½″ long, 32′ 1″ deep
Ceiling Height—13′ 4″ (next to panel)
11′ 9½″ (next to windows)
Sash Sill Height—44½″
Block Sill Height—9′ 4½″

Block Panel—6 courses high by 60 wide
Sash—fixed aluminum frame, canopy shaded
Area Ratio—Panel to floor, 12.5 per cent
Sash to floor, 33.8 per cent

Note: Panel is partially shaded by ventilator fans and adjacent building.

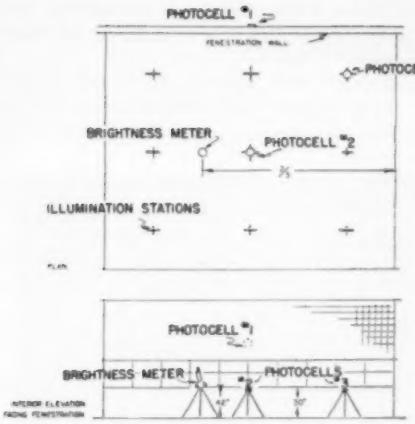
Reflectances: Floor, 30 per cent, asphalt tile; walls 50 per cent, blue-green; ceiling and above dado, 75 per cent, acoustic tile.





Average brightnesses in footlamberts, above left; illumination in footcandles, above right.

Condition 1—1:20 P.M.; sky is clear; exterior illumination of block panel is 4600 footlamberts; sun altitude is 60-65 degrees; sun azimuth is —25 degrees to normal-to-panel.



(Top) Plan view of apparatus set-up; (below) interior elevation, facing fenestration.

INSTRUMENT SET-UP

1. "Control" Readings

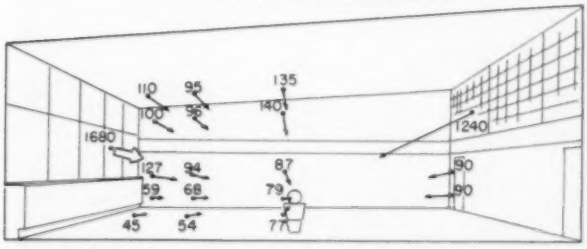
a. Mount fixed photocell #1 in vertical exterior plane of fenestration. Connect to footcandle meter #1 (inside room) by long lead wires.

b. Mount fixed photocell #2 in horizontal plane 30 inches above floor at center point of room and connect to footcandle meter #2 located for convenient simultaneous reading with meter #1.

2. Performance Data

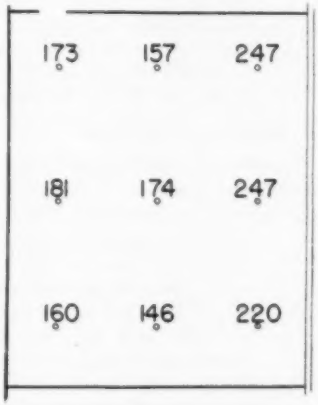
a. Mount photocell #3 in horizontal plane 30 inches above floor on a movable platform, tripod or other level surface. Connect by long lead wires to footcandle meter located for convenient simultaneous reading with meters 1 & 2.

Results of daylighting survey (continued)



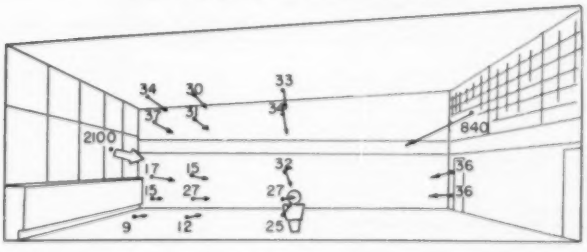
Average brightnesses in footlamberts, above; illumination in footcandles, right.

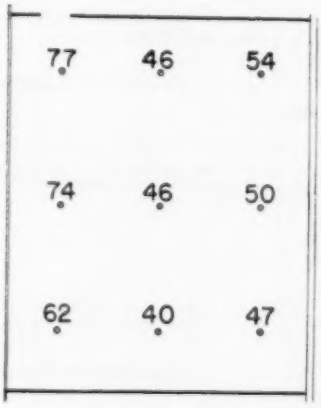
Condition 2—2:30 to 3:35 P.M.; sky is clear; exterior illumination of block panel is 7400 footcandles; sun altitude is 35-50 degrees; sun azimuth is 20-40 degrees from normal-to-panel.



Average brightnesses in footlamberts, below; illumination in footcandles, right.

Condition 3—5:05 to 6:44 P.M.; sky is clear; exterior illumination of block panel is 1650 footcandles; sun altitude is 35-20 degrees; sun azimuth is 45-55 degrees from normal-to-panel.





b. Mount fixed brightness meter 42 inches above floor on centerline of room ⅔ distance from front to rear walls. This meter should be on a transit tripod, pan-head tripod or other steady universal mount.

Photocells should be color and cosine corrected. (Daylight color varies widely and much light from some types of unilateral fenestration enters at near grazing angles.) Cell #1 and meter #1 should cover the range 250-10,000 footcandles. Meter #2 should cover range 10-300 footcandles. Meter #3 should cover range 5-500 footcandles. Check calibration of all meters.

Procedure

1. Brightness Readings

Brightness observer aims brightness meter at first of series of at least 18 predetermined points in field of view on fenestration; ceiling; front, inside and outside walls and floor (points to provide reasonable coverage of each surface). Balance meter and read brightness; recorder simultaneously reads footcandle meters 1 and 2. Repeat this process at least 3 times for each point.

2. Illumination Readings

Movable photocell #3 should be placed at first of series of 9 predetermined stations in room (see drawing). While the three brightness balances are being determined for each point, record one photocell #3 reading, along with simultaneous readings for photocells #1 and #2. Then move to next station. (Result: For each run, two readings at each illumination station when brightness is measured at 18 points.)

For best results, work should proceed rapidly to minimize continuous variation in exterior conditions.

Analysis and Report

Analysis

Determine average photocell #1 reading for run. This represents average fenestration illumination.

Determine average photocell #2 reading for run and proceed as follows to adjust all other readings:

a. Multiply each photocell #3 reading by the ratio of the average photocell #2 reading to the simultaneously recorded photocell #2 reading.

b. Average the results of the three or more brightness balances for each point and multiply each average by the ratio of the average photocell #2 reading to the simultaneously recorded photocell #2 reading.

Report

Date, Time and Location of Survey.

Room dimensions, fenestration details and dimensions, orientation of fenestration wall, local obstructions if any, daylight controls, surface reflectance.

Average Exterior Illumination of Fenestration. Sun azimuth and altitude with respect to a line perpendicular to the plane of the fenestration. Weather conditions.

Conclusion

The application of automatically recording meters to this method is under development. The prospects are that much greater speed may be achieved with no loss in accuracy. The time when we can correlate daylighting performance with weather bureau records is rapidly approaching.

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Museum Case Lighting

LIGHTING OBJECTIVE: To provide a high level of shadowless illumination throughout a display case.

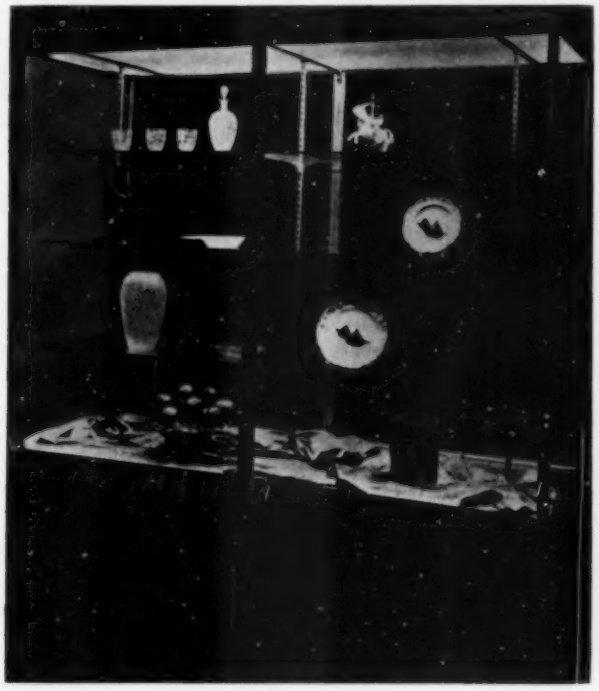


Figure 1.

Installation at Remington Rand, Inc., 315 Fourth Avenue, New York City.

General Information: The double-faced glass-topped display case shown in the photograph is 78⅝" wide, 32" deep, and has 61⅛" of vertical display space. The glass shelves are ¼" thick.

Installation: On all four sides of the top of the case are mounted 3500K T6 fluorescent lamps in reflectors as indicated in Fig. 2.

Figure 3 gives the resultant illumination levels. Annoying reflections are minimized and all details are fully visible.

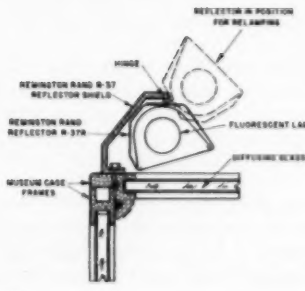
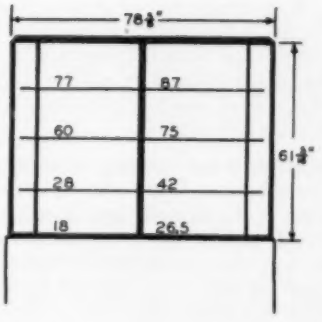


Figure 2 (left). Section of exterior lighting applied to top of case.

Figure 3 (right). Footcandle levels on shelves. Measurements at left with opaque objects on shelves; right, no objects on shelves.



Lighting data submitted by H. R. Datz, Library Bureau, Remington Rand, Inc., 315 Fourth Avenue, New York City as an illustration of one solution to a lighting problem and to aid in the design of similar installations.

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Psychological Aspects of Color and Illumination

By RALPH M. EVANS

This report to the Committee on Color in Light and Illumination presents the concepts and questions of possible psychological factors concerned in color and illuminating engineering.

THE GENERAL problem before the committee is to introduce the concept of efficiency into the field of color in lighting. It is the task of learning the most efficient way of producing the result desired by the engineer or his client and the shortest and most reliable path toward such a use. It must be remembered that this efficiency may include the work output of the people exposed to the environment which the engineer creates. It is not limited to the cost of installation nor operation, although these will be important factors with the client.

It should also be stressed at somewhat more length than appears below, that in the field of color the lighting engineer needs the assistance and cooperation of people from other groups and professions. In his turn it will often be necessary that he also give wholehearted cooperation to these other people. The effect of a lighted environment includes everything (even the geniality of the proprietor). If lighting is to be an integral part of the result it must be made so by carrying out into all its details a carefully preconceived plan. It may be the lighting engineer who conceives this plan or it may be the interior decorator or the art director or the architect or even the client. In any case everyone must work together.

It is perhaps not out of place to suggest that the Society's membership in the Inter-Society Color Council can be used advantageously in supporting and producing such an attitude of mutual cooperation. In any case it is the duty of the committee to further such relations.

Absolute White.—Perhaps the first problem before the committee is to define its own scope. In one sense of the word all light sources are colored and in this broader aspect the task of the committee is to study the consequences of that fact. In another sense all sources are colored *except* certain ones which are often called white or achromatic. To date there is no agreement on what light sources look achromatic under what conditions, although ICI Illuminant C is often used for this purpose. This is the problem of "absolute white." It seems a logical problem for attack by the committee.

Q. What illuminant energy distributions under what conditions appear without hue to the observer?

Q. To what extent does the selectivity of the environment affect the apparent color of the illuminant?

Helson-Judd Effect.—There are a host of corollaries to this problem of the color of light sources. The so-called Helson-Judd Effect states that after color adaptation to a neutral environment illuminated by a source having a certain color with respect to daylight, the light source itself and the brighter parts of the environment will have this color, a lesser brightness will appear achromatic, and the brightnesses lower than this will become progressively more saturated in a complementary hue.

Q. What are the consequences of the Helson-Judd Effect in illuminating engineering?

Q. Under what conditions does a non-selective surface of a given reflectance appear without hue?

Q. What are the conditions under which the complementary colors of the shadows become objectionable to the observer and to what extent is this dependent on the brightness distribution of the environment?

White.—It is important for the committee to take a definite stand on the meaning of the word "white." At present it is being used indiscriminately to describe any hueless high brightness area, whether a light source or a reflecting surface. However, a piece of white paper under tungsten light is certainly not without hue in any real sense, and many psychologists insist that white is necessarily a characteristic of surfaces rather than light sources. The writer believes that the word "white"

Color Control Department, Eastman Kodak Company, Rochester, New York.

actually is a description of the diffusing properties of an object.

Q. What is the proper definition of the word "white"?

Gray and Black.—Since a surface which would normally appear white can be made to appear gray or black with little difficulty (motion picture screens, for example) and an absorbing surface can be varied in like manner, it is apparent that gray or black are not properties of surfaces but of the illumination and observer. The same fact holds for selective surfaces.

Q. What are the factors determining the shade of gray which a given non-selective surface will appear under any given set of circumstances?

Q. To what extent can the answer to the previous question be applied to selective surfaces?

Q. What is the maximum intensity which will appear black under a given set of conditions?

Selective Surfaces.—Many very difficult problems are awaiting solution which involve the appearance of a selective surface in an illuminated environment. Perhaps the most important of these deals with the relative appearance of a given surface in daylight and in artificial light. Although a number of suggestions have been made as to how such appearances might be calculated, no careful study has yet been made which includes the factors of energy distribution, environment distribution and observer adaptation. A proposal is now pending before the I.E.S. Research Fund for such an investigation.

Q. How can the appearance (hue, saturation and lightness) of a selective surface in a given environment under a given illuminant be calculated?

Q. Specifically, what are the illumination factors which influence the perceived color of an object and what are the quantitative relations involved?

Modes of Appearance.—Both in connection with the previous questions and some of those which follow it is necessary that the *way in which the observer is seeing* be taken into account. In part this is a purely personal phenomenon as in cases where one person may be trying to recognize a person at a distance in a restaurant while another is enjoying the appearance of the room as a whole. On the other hand, the illuminating engineer's task of creating an illuminated environment must be directed toward making the appropriate type or types of perception easiest in a particular case. It it necessary, therefore, that the factors having maximum tendency to produce a given type be known and understood. Perhaps the best published listing of these types or modes is that of the OSA Colorimetry Committee. Four modes are listed as follows: Aperture, Illuminant, Illumination and Object (Volume and Surface). Some of these are discussed in later sections.

Q. What are the illumination conditions under which each of the above four modes of appearance have the maximum tendency to appear?

Q. What conditions produce a minimum tendency?

Q. Under what conditions is it desirable that any of these be emphasized or minimized?

Attributes of the Modes of Appearance.—Perception can take place in one or more modes simultaneously or successively. Under each of the modes, however, only certain aspects of the situation can occur. These are called the attributes of the modes. Again the most carefully thought out listing is that of the OSA. The report lists eleven attributes, of which the first five can occur in the aperture mode, the first eight in the illuminant mode, the first three in the illumination mode, all eleven in the object surface mode and the first nine in the object volume mode. The list is as follows:

1. Brightness (or lightness)
2. Hue
3. Saturation
4. Size
5. Shape
6. Location
7. Flicker
8. Sparkle
9. Transparency
10. Glossiness
11. Luster

So many questions of importance to illuminating engineers are raised by these attributes that some of them must be discussed separately. The general question underlying all of the problems, however, deals with the enhancement or suppression of the attributes individually.

Q. What is the effect on each of the attributes of:

a. the geometry of the illumination?
b. the intensity of the illumination?
c. the color of the illumination?
d. the temporal characteristics of the illumination?

Q. To what extent is eye fatigue connected with attempts to see or not see a particular attribute under particular conditions?

Brightness and Lightness.—There has been much confusion in the literature and in the thinking concerning the difference between seeing the relative

amount of light which reaches the eye from a given area (the appearance of which is here called brightness) and seeing what the percentage of the incident light is which is reflected from a given area toward the observer (the appearance of which is here called lightness). In any extreme case the difference between them is tremendous, a dark gray being much brighter than a white, although being seen as a lower lightness. The phenomenon is the familiar one of a piece of white paper continuing to look white wherever it is placed in a room regardless of the incident illumination. The extent to which the observer tends to see lightness or brightness or both depends on:

a. The training, past experience and intentions of the observer.
b. The lack of uniformity of illumination (brightness and lightness are identical in completely uniform lighting).
c. The extent to which the non-uniformity of illumination is visible to the observers.
d. The reflectance of the surface (lightness perception decreases with per cent reflectance).
e. The selectivity of the surface (function not known).

Most completely naive observers tend to see lightnesses when conditions are favorable and attempt to do so when they are not. Observers trained in looking for visual effects (painters, photographers, illuminating engineers, etc.) either can see one or the other at will or tend to see brightness. Very few observers can actually see true reflectance (except perhaps for very high reflectances) or true luminance (except perhaps for very low reflectances in bright light) but the facts in general are not known quantitatively in spite of a number of excellent investigations.

In general less detail can be seen in regions of lower brightness in a given environment even though this region appears of equal lightness.

Q. What are the quantitative relations involved in perceptions of lightness and brightness, specifically:
   a. What are the statistical distributions among classes of observers?
   b. How does the perception vary with illumination non-uniformity?
   c. To what extent must the illumination be perceived?
   d. How does the perception vary with per cent reflectance?
   e. How does the perception vary with the color of the surface?
   f. What are the rules followed by the loss of detail?

Q. To what extent is the attempt of the observer to see true reflectances in non-uniform illumination a factor in visual fatigue?

Q. To what extent is the attempt to see the same amount of detail in areas of different brightness a factor in visual fatigue?

Q. Does loss of lightness perception occur under fatigue?

The brightness of a given area is dependent on both the areas which immediately surround it (simultaneous contrast) and on the general environment (adaptation level) as well as on the preceding area viewed by the observer (local adaptation or after-images).

Q. How can the adaptation level be determined?

Q. What is the effect of a given adaptation level on the appearance of a surface of given reflectance?

These effects may aid or oppose the perception of lightness.

Q. What are the quantitative laws followed by simultaneous contrast?

Q. To what extent may simultaneous contrast affect the perception of lightness?

At the present time the I.E.S. recommends that brightness ratios in a working environment be held to a ratio of 3 to 1 or less. As defined in this case, brightness means the luminous intensity of the light reaching the eye.

Q. In view of the above considerations is the requirement that stated, or should it be illumination ratio, or lightness ratio?

Absolute Brightness.—Brightness in the I.E.S. is defined as luminous intensity. That is, it is a measure of absolute intensity. However, it is usually understood that the eye is not a photometric instrument but responds primarily to relative brightnesses. That the eye does have some ability to assess absolute brightness is shown by the fact that a dark overcast day is easily distinguishable from a bright overcast day usually as well as by measurement. On the other hand many situations such as the lighted stage in the theater or a brilliant ball room may look as bright or brighter than the bright overcast day even though measurements show that the illumination level is lower than the dark day. In some cases at least, this reversal of appearance seems to be due to the contrast of the illumination, i.e., its non-uniformity.

Q. What factors determine the appearance of absolute intensity of a given illumination?

Q. To what extent does non-uniformity of illumination make the illumination level appear greater than it is?

Q. How is the appearance of absolute intensity related to the adaptation level existing at the time?

Hue.—The hue of an illuminated area or a light source is determined to a great extent by the effect of the environment on the observer's eyes. We are not normally aware of this since we do not have experience with any large number of sufficiently different environments. The hue seen is affected by the selective energy distribution of the source of light, the selectivity of the environment and other factors. The net result is dependent on the evaluation of these produced by the state of color adaptation of the observer. In addition, of course, simultaneous contrast affects local hue as well.

Q. What are the factors and laws which must be taken into account before a calculation may be made of the hue of a particular energy distribution to an average observer in a given situation?

Q. How can the calculation be made?

The visual color of the energy distribution and not its energy distribution as such is the determining factor in color adaptation. Accordingly, selective surfaces may or may not look the same under illuminants of different color and in general will not under two which look alike but have different energy distributions. The illuminants to which we have been accustomed until recently have nearly all approximated the energy distribution of complete radiators or black bodies (daylight and thermal radiators).

Q. How far can the energy distribution of a light source depart from that of a black body without serious hue shifts in familiar objects?

Q. What are the requirements of a selective surface which will make it appear approximately the same under daylight and tungsten light?

When two light sources throw a shadow of the same object on a surface otherwise illuminated by both lights, these shadows will appear complementary in hue if there is a difference in color of the two lights. If the lights are of nearly the same color, however, the saturations of the colors in the shadows will be very low since these saturations increase with the color difference between the two.

Q. What is the minimum color difference between two lamps which will produce objectionably colored complementary shadows?

Q. What is the minimum perceptible color difference between such shadows?

Saturation.—Saturation has been variously defined by different groups and at present appears to have no official definition in the I.E.S. (This is a general situation for all psychological terms.) It is ordinarily used to denote the amount of hue in a color according to some specified scale of units. Since it refers to the perceived amount rather than the physical stimulus, it varies with the absolute illumination level, the relative level, the color and energy distribution of the source and the selectivity of the area as well as the color adaptation status of the observer's eyes. There appear to have been no studies on its relation to such factors as the brightness-lightness perception in a given situation.

Q. What should the I.E.S. adopt as a definition for saturation?

Q. What are the factors involved in its perception and what are their quantitative relations?

Q. What is the relationship between saturation and lightness and brightness?

Size, Shape and Location.—Size, shape and location are geometrically defined properties of an object in an environment. As seen by an observer, however, they are markedly determined by the nature of the environment, and in particular, by the illumination of that environment. They would not appear, however, to come within the scope of the color committee.

Flicker.—Flicker in an illuminated area may be due to movement of an object or to an illuminant which changes in intensity with time. If both occur, flicker may be set up by stroboscopic action even though neither shows flicker by itself. Under certain circumstances, color effects can be observed.

Q. Are color effects from flicker ever sufficiently important so that they should be considered?

Sparkle, Transparency, Glossiness and Luster.—Each of these attributes depends for its perception on the geometry of the illumination and the orientation of the object with respect to the observer. It is unfortunately true that the geometry of the illumination can also make an object appear to have characteristics which it does not possess. Thus a glossy object in completely diffuse light does not look glossy but dull and of low saturation. In directional diffuse light the same object will appear to have a satin finish, etc.

Q. For each attribute what nature of illumination geometry must be avoided if the attribute is to represent the true properties of the object?

Hue and Saturation vs. Lightness.—Current practice is tending toward high reflectance surfaces in uniform illumination in order to minimize the brightness contrast of the working environment and increase the efficiency of the illumination in terms of brightness. In order to retain contrast between objects, selective surfaces are being used.

Hue and saturation, however, are not like each other and neither are like brightness as perceptual variables. Hue tends to produce emotional responses as does saturation while contrast as such lies largely in brightness differences. Some writers even go so far as to identify hue with emotion, claiming, for example, that the hue red *is* an emotion all by itself, and that saturation is a matter of the intensity of the emotion. Without going this far, however, it is possible to make some such statement as the following. In any given scene hue differences provide variety, saturation differences provide subtlety and brightness differences provide life and vigor.

Q. To what extent is it permissible to substitute hue and saturation for brightness differences without careful consideration of the aesthetic, psychosomatic and affective character of the result?

Q. To what extent is such a substitution possible to get the same visual efficiency?

Diffuse and Directional Illumination.—In many of the above questions the geometry of the illumination has played an important role. Two extreme types of this geometry merit careful consideration. Diffuse light can be defined roughly by the statement that it does not throw sharp shadows of objects and directional by the fact that it does. Present day trends appear to be toward diffuse lighting. This suggests many problems based on the earlier discussion. One further point needs to be considered. If the apparent absolute intensity level is a matter of lighting contrast, it may well be that efficiency in terms of *apparent intensity* per watt decreases with increasing perfection of the diffusion, in spite of recent improvements in *actual* intensity per watt.

Q. To what extent do objects appear to have their correct properties in diffuse as opposed to directional illumination?

Q. Under what conditions is very diffuse light desirable?

Q. Is diffuse illumination as efficient per watt in terms of *apparent* amount of light as directional?

Color of Walls.—In order to increase the utilization of light and hold down the environment contrast, it is customary to maintain a high wall reflectance in certain types of environment. Because white tends to become monotonous, these walls are usually colored at moderately low saturation. The fact that these walls are increasing the efficiency means that they are acting as secondary sources.

Q. To what extent can walls be made selective without getting into trouble because of the effective change they produce in the color of the light source?

Illumination and Illuminant.—For many of the attributes to be seen correctly it is necessary that the illumination falling on objects be clearly perceived. This is particularly true for the attribute of lightness as noted above. Perhaps the most important indication of the illumination is the position and nature of shadows. Secondary indications come from illumination gradients, glossy reflections, etc. For some sorts of perception it is probably necessary that the illuminant itself be seen as such although this condition is usually met.

Q. What are the factors which aid in the direct perception of illumination as distinct from object properties?

Q. What are the object attributes the correct perception of which depends on well developed illumination perception?

Q. To what extent is direct perception of the illuminant necessary or desirable?

Engineer—Decorator—Designer—Architect—Consultant.—When the illuminating engineer starts to consider color in a given environment, he finds that, including his own, there are at least five well defined groups in the field. A representative of any of the groups may find himself expected by the client to handle the color of the environment as part of the job. The illuminating engineer, the interior decorator, the industrial designer and the architect are each expected to be able to handle color and there is in addition the growing group of color consultants who make it their job to assist any of the others. While there would seem to be no point in attempting to limit the activities of any of these groups, it might be a valuable contribution for the committee to define what might be called the "proper" sphere of the illuminating engineer in this respect.

Q. Under what conditions and to what extent is it desirable that the illuminating engineer be the one who specifies the colors applied to an environment, including the colors of the light sources themselves?

Q. How far along the progression, engineering, decoration, art is the client justified in assuming an illuminating engineer capable of handling the job?

Affective Response to Colors.—Assuming that the illuminating engineer must necessarily specify the colors to be used in many situations, a whole group of problems arise as to the effect of these on the

individuals using the environment he creates. Not a great deal is known in this field although much has been written. It would be an important contribution from this committee if it were to collect and consider this material if for no other reason than to point out the directions in which research should be undertaken. The various types of response which can be produced by color are listed in part in the following sub-headings. A more complete listing would be useful.

Q. What are the various ways in which color in an environment can affect people?

Q. To what extent is it permissible to consider that the color scheme of a room can be chosen with no other criteria than color harmony and light utilizatinon, i.e., to what extent must human reaction to colors *as such* be taken into account?

Aesthetic Response.—Much work has been done on the subject of harmonious color combinations and several engineering approaches have been recommended. The colors to which the majority of people are indifferent and which, accordingly, are quite safe to use have been compiled recently. Work is now pending on a study of preferences for individual colors. It appears a logical task for this committee to attempt to collect and correlate this material but it raises the question immediately of how far such considerations are the concern of illuminating engineers.

Q. What is the present status of the engineering design of harmonious color combinations for a given situation?

Q. May indifferent colors be used under all conditions, and if not, what are the restrictions?

Q. To what extent does preference for individual colors apply to color combinations?

Character or Mood of an Environment.—It is reasonable for a client to request that a particular room or other area be so lighted that it will be gay, quiet, somber, lively, practical, austere, etc. To the extent that the illuminating engineer is involved the chief difficulty is one of finding an approach to the problem. Lighting is perhaps the major factor in the production of such effects.

Q. What are the relationships between geometry, intensity, and color quality of the illumination and the emotional effects and impression produced in the observer?

Q. What general rules can be laid down?

Attention Value of Color.—Much is known about the attention value of colors although it has not been carefully collected and correlated.

Q. What are the main factors in attention value of colors and color combinations?

Q. How can attention value be made maximum and how minimum?

Warm and Cool Colors.—A controversy is in the making as to whether the expressions "warm" and "cool" colors have any meaning. It appears to be established that such environments do not make people feel the temperature is higher or lower but it is doubtful if this is the meaning of the term. A clarification would be helpful.

Q. What are the meanings of the words "warm" and "cool" when used in connection with colors?

Psychosomatic Effect.—Of great interest to illuminating engineers is the effect of color on the health of individuals. Much work is being done in this field but the results are not widely known nor entirely understood. It has been demonstrated that color can help speed recovery of convalescents and the like and hence has therapeutic value. It is not so well known to what extent color can be harmful to the health. It certainly can be depressing and it would seem to follow that it can produce harmful mental, if not physical, effects.

Q. What is the relationship between color in an environment and the physical and mental health of an individual exposed to it frequently for long periods?

Task of the Committee.—It would appear that a major task of the committee is to collect, analyze, study and publish as much as possible of the above material so that the knowledge can be reduced to practice in the form of a true engineering approach to color in lighting.

Watch for the May Issue

Good lighting aids increased industrial production —so said countless industrialists during the production push during World War II. An even greater industrial effort is now under way. The importance of illuminating engineering to this effort is the theme of the May issue of ILLUMINATING ENGINEERING. Essential tables and highlights of the proposed American Standard of Industrial Lighting will be presented, together with numerous articles on industrial lighting techniques.

Muscle Action Potentials as a Measure of Visual Performance Cost

By ROLAND C. TRAVIS, JOHN L. KENNEDY, LEONARD C. MEAD, and WILLARD ALLPHIN

Introduction

IT IS known that with a dark surround acuity increases with illumination up to 10 or 15 footcandles and that with a uniform surround it increases with illumination up to 1,000 or more footcandles.[1]

There is also laboratory evidence that performance increases with illumination,[2] although the Hawthorne tests of some years ago threw doubt on the ability of lighting to increase production in an actual industrial test.[3]

Even if acuity and performance rise with illumination, we are still left with the question of whether or not the increases are had at the expense of greater demands on the human organism. What is the actual physiological cost of seeing? In other words, applying the familiar engineer's formula:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

to the seeing mechanism, how can we measure the input?[4, 5, 6]

Methods of measuring physiological cost only recently have been refined sufficiently to give promise of a reliable and dependable method. The Tufts Psychological Laboratory has been working a number of years on standard equipment in the electrical recording of brain waves and muscle action potentials, and especially in the development of new electronic amplifiers and integrators for studying brain wave patterns as well as muscle action potentials as applied to states of alertness, tenseness of the body in various occupations and the like.[9, 10, 11, 12, 13, 14]

One of the most practical of these devices, the "alertness indicator," uses muscular action potentials to measure the alertness of the subject. Obviously the illumination level which produces the lowest possible alertness potential would not be the most desirable one because this would be for a state of sleep. However, it can be argued that the lowest tension level at which the subject maintains optimum performance is the desirable one.

With this in mind, it was arranged to measure reading rate and muscle action potentials for different levels of illumination with the level changing so slowly as to be unnoticed by the subject.

Reading was chosen for the first experiments because it is a habitual and well-standardized task which is relatively free from learning effects and need not change appreciably after long, continued performance.

Method and Procedure

Illumination controls. — The subject was seated before a small table in a ventilated, sound-reduced room, six feet long, four feet wide, and seven feet in height, Fig. 1. The walls and floor of the room were covered with aluminum paint which pro-

Figure 1. Subject in test position with electrodes in place. Part of luminaire can be seen overhead. The circular apparatus has no connection with these tests.

Authors: Roland C. Travis, John L. Kennedy, Leonard C. Mead of the Institute for Applied Experimental Psychology, Tufts College; and Willard Allphin of Sylvania Electric Products, Inc.
A research project conducted under the sponsorship of the Illuminating Engineering Society Research Fund.

duced a soft gray effect. The table (36 in. by 23 in.) was covered with mist-green desk linoleum which provided a neutral background. A small stand which held the book at a right angle to the line of sight was placed at reading distance from the subject.

A fluorescent luminaire 45 inches long and 36 inches wide, capable of holding a maximum of twenty 42-inch slimline fluorescent lamps,* was mounted about 6 inches from the ceiling. One electric fan served to cool the lamps in this compact luminaire. Another fan was used to ventilate the room.

A louver-shutter to control the output of the luminaire was mounted about 2 inches below the surface of the fluorescent lamps. A piece of opal white lucite (45 in. by 31 in. and $\frac{1}{8}$ in. in thickness) to aid in diffusing the light was mounted just under the louver-shutter. The lucite screen was 34 inches above the center of the reading page. Transmission tests showed that the lucite screen cut down the lumen output by about 30%. The illumination could be changed from 220 footcandles down to one-fifth of a footcandle within 5 minutes at the fastest rate and to 5 hours at the slowest rate.

Reflectivities and Brightnesses. — The linoleum desk top had a reflectivity of 35% and the aluminum wall paint 38% but where the luminaire was reflected as a bright area on the wall, this brightness gave an apparent reflectivity of 68%. The glint effect thus produced gave a gradual transition in brightness from the lower wall to the luminaire on the ceiling and it will be seen from Fig. 1 that the luminaire was outside the normal field of view.

Brightnesses in footlamberts for a typical setting of the controls were: desk top 9.5, book page 18.5, lower wall 4.3, upper wall 43, luminaire (general area) 110, luminaire (brightest area) 450.

Recording of muscle action potentials. — It is well known in physiology that muscle tissue exhibits measurable electrical potentials during contraction and a number of valid electronic devices have been used for years in recording the amplitude and frequency characteristics of muscle action potentials.

Previous intensive research in the Tufts Psychological Laboratory in developing an electronic device to predict states of alertness by recording muscle action potentials resulted in a method to measure continuously the muscular tension level of a person during the performance of a task.

Briefly, the alertness indicator receives, amplifies, and integrates the muscle action potentials over a given interval of time (one second). The integrated potentials may be read continuously from a meter or recorded on a continuous tape. The electrodes are mounted two inches apart in a headband and when in place, action potentials from the muscles just above the eyebrows are recorded.

Previous research has shown a close correspondence between muscle-tension level as measured on dynamometers and the muscle action potential output from the forehead region. The well-established measure of reaction-time has a very close correspondence to the magnitude of muscle potential output. The more alert and the shorter the reaction time, the higher the muscle potential output.

Accuracy of performance in two different tasks, first, continuous tracking (simulated motor car driving) and second, number of units assembled per unit of time in a simple assembly task were closely associated with muscle potential output. Tasks which place added strain on the visual system also increase the muscle potential output from the forehead region. The amount of strain placed on the muscles associated with the visual system and the magnitude of the muscle potentials from the forehead region approximates a linear relationship.

The tension level, as indicated by the muscle potentials from the forehead, may be changed in a number of different ways. Contraction of the facial muscles, moving the scalp, closing the jaws, lifting weights in the hands, squeezing the hand dynamometer, maintaining alert visual attention, all increase the muscle potential output from the forehead region. Any increase in alertness or muscle tension throughout the body results in an increase in the muscle potential output. States of inalertness and relaxation result in a diminution of muscle potential output.

Thus, it is reasonable to suppose that in a reading task anything which places extra strain on the visual system would result in a higher muscle potential output from the forehead region. We would expect a higher muscle potential output in reading under illumination intensities which demanded close scrutiny and a slowing down of reading rate in order to maintain visual acuity for reading. Furthermore, if the reader succeeds in maintaining a normal reading speed under low illumination, a higher tension level would be expected.

Preliminary experiments with two subjects, in

*Warmtone lamps were used.

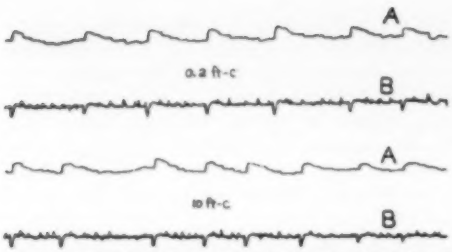


Figure 2. Portions of tape record of eye-movements of one subject during reading under two illumination levels —0.2 footcandle and 10 footcandles. A and B are different channels with slightly different filtering systems.

moving the reading material out to twice the comfortable reading distance, resulted in an increase in muscle potential output from 3 to 6 microvolts. One of these experiments is plotted in Fig. 5. The tension level dropped immediately when the reading material was brought back to normal reading distance.

The fact that the vast majority of occupations include vision as a major component makes the use of this electronic device a promising method in studying the effect of illumination levels on the physiological economy of the worker.

Recording eye-movements as an indicator of continuous performance. — The electronic recording of eye-movements during reading has proven to be an accurate way of indicating the speed of reading.[7, 8] The so-called corneo-retinal potential is of sufficient magnitude to indicate admirably the return sweeps in refixating from line to line.

Preliminary trials using illumination levels on the book of 220 footcandles down to 0.4 footcandle showed such small variations due to illumination that it was decided to use 40 footcandles as the upper limit and 0.2 footcandle as the lower limit in further preliminary experiments. Most of the following results are based on the change in illumination from 30 to 40 footcandles down to 0.2 footcandle.

The shutter control-unit was set to change the illumination at a constant rate from the high to the low level in approximately eleven minutes, a rate slower than the dark adaptation of the eye. The experimental session was begun at the high illumination level and the cycle of going down and up was repeated for each session.

Preliminary Results

Two portions of a record for one subject at two illumination levels, 10 footcandles and 0.2 footcandle are shown in Fig. 2. Line A shows the corneo-retinal potentials during reading as recorded in steps on one channel of the electrical recording system. Line B shows the same corneo-retinal potentials recorded on another channel with a slightly different filtering system. The large deviations in both lines A and B were the return sweeps of the eyes at the end of a line. The small deviations were the jumping movements of the eyes in reading from word to word or from phrase to phrase.

It will be seen in comparing the reading rates for these two illumination levels that the rate for the 10-footcandle level was about 14% faster than for the 0.2-footcandle level for these particular portions of the records for this subject.

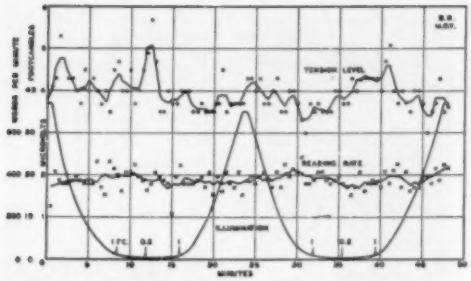
Two subjects showed greater variability in tension level. Four subjects showed on the average a small increase in tension level during the low illumination periods.

Two subjects exhibited great increases in tension level due to interest or motivational factors. One of these subjects had just received the news that he was to take a cruise on a submarine and for several minutes after the beginning of the experiment his tension level was abnormally high. The other subject became increasingly more interested in the story ("The Mystery of Y") as the end of the experimental period drew near, resulting in a great increase in tension level.

The motivational factor is a serious problem in all attempts to control experimental procedure with human beings. No two persons react exactly the same in this respect in any experiment. We attempt to minimize motivational factors by having standard procedures, elimination of excessive stress and strain, elimination of irrelevant light, noise, etc., and by building up certain mental attitudes with appropriate instructions using well-established habits of cooperation. However, at best, motivation is largely uncontrolled.

Figs. 3, 4, and 5 show the results of three runs graphically. Because the reading rate was measured in terms of lines per half minute, each line averaging 9 words, it seemed reasonable to smooth the curve somewhat. Therefore, a moving average was used, each point on the curve being the average of the five nearest readings. In the curve of muscle action potential, each point is the moving average of three readings.

Naive subjects were used in the tests plotted in Figs. 3 and 4, that is, they did not know the purpose of the test and did not realize that the illumination was changing until the level had reached about 1 footcandle at which time they became aware of lowering illumination. The subject in Fig. 5 did know the situation but his performance in many other tests in the same laboratory has in-



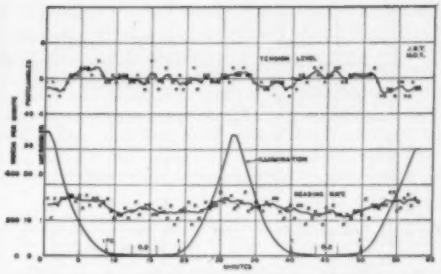


Figure 3 (Left). Subject B. E., reading "Mystery of Y." Curve for tension level is a moving average of three points. That of reading rate is moving average of five points. Figure 4 (right). Subject J. R. T., reading "Mystery of Y."

dicated his ability to maintain a detached viewpoint.

In Fig. 3 the reading rate was apparently not influenced by the illumination level but there was possibly some effect on muscular tension. Fig. 4, on the other hand, shows no change in tension level but does show a faster reading rate with higher illumination.

In Fig. 5 there was a slow increase in muscle action potential, independent of illumination, except for the unexplained rise and fall near the end of the first run. The reading rate rises somewhat with increased illumination. In the second run, which followed the first one after 10 minutes, the book was moved to twice the normal reading distance for the shaded portions of the curve. For the unshaded portions the book was returned to normal reading distance for that subject. The increased distance brought about a marked increase in muscle action potential, which seemed to be independent of the illumination level.

One run was made with a more severe reading task with the results shown in Fig. 6. The book was an old copy of "Don Quixote" in 8-point type in faded ink on yellowed paper. Here the reading rate was directly proportional to the illumination and changed more than in any of the other tests.

The muscle action potential had a pronounced upward trend through the period of falling and low illumination, declined briefly when the illumination increased, then resumed its upward trend.

Conclusions

Considering the preliminary nature of the tests, any conclusions must be tentative, but in view of the faithful monitoring of tension-level in the human subject by the alertness indicator technique, the satisfactory electronic recording of eye movements as indicative of reading performance, and an adequate method of controlling illumination level, it would appear that an overall-technique may soon be available for studying illumination standards desirable for various occupations.

If further tests should confirm the preliminary results, it could be said that:

For reading 10-point type in a surround providing comfortable brightness ratios, the physiological cost does not increase at very low levels of

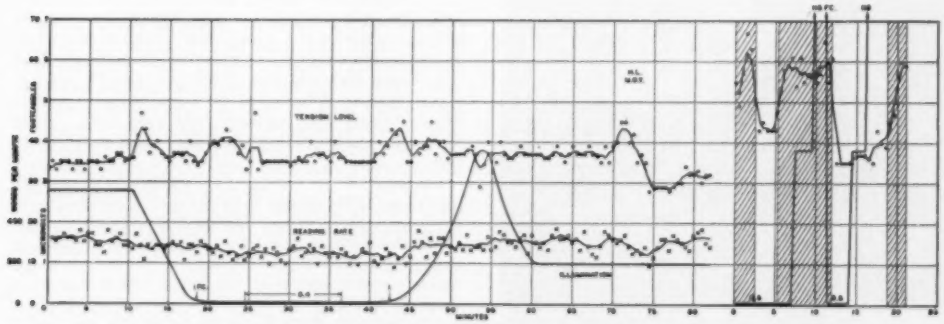


Figure 5. Subject H. L., reading "Mystery of Y." During shaded portions the book was moved to twice the subject's normal reading distance. Reading rate was not recorded during latter part of test.

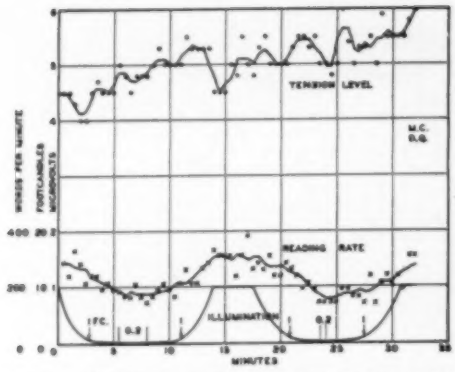


Figure 6. Subject M. C., reading "Don Quixote." Faded type and yellowed pages.

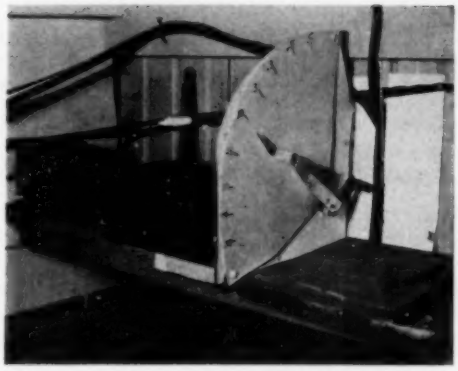


Figure 7. Illumination control apparatus. Scale marked in footcandles at book.

illumination for periods of from 10 minutes to 30 minutes.

Under the same conditions, except that the reading rate is maintained, the physiological cost increases somewhat at low levels of illumination.

When the severity of the task is increased, the reading rate becomes more directly proportional to illumination and the physiological cost increases immediately both with low illumination and with elapsed time.

Discussion and Recommendations

If similar results are obtained when tests are extended over periods of several hours, it would indicate that as far as physiological cost alone is concerned, there is no need for high footcandle levels when reading a well-printed book in a comfortable surround. However, Fig. 6 indicates that tasks of greater difficulty will require more than minimum illumination for lowest physiological cost.

The following are suggested for further investigation:

1. A continuation of the tests already described.
2. Reading 10-point type in a comfortable surround at low illumination levels for long periods of time.
3. Reading at different illumination levels in a dark surround for long periods.
4. An analysis of industrial and commercial tasks in terms of tension level as affected by illumination.

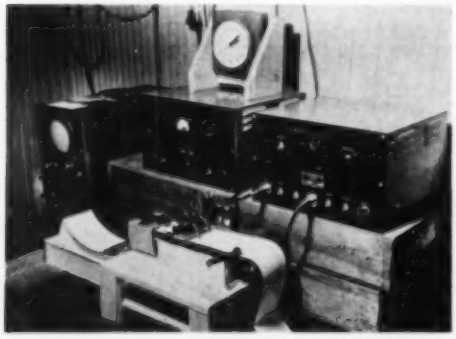


Figure 8. Alertness Indicator. Left to right: Cathode-ray oscilloscope, calibration unit, amplifier and integrator. Foreground: recorder.

Appendix — Method and Procedure

Illumination Controls. — The louver-shutter contained 22 pivoted louvers (2 in. wide and 32 in. long) all fastened to a control lever in a manner to permit an approximate uniform reduction in the illumination levels throughout the room, eleven louvers on one half of the shutter revolved in one direction. This prevented a directional effect in the lighting, the plastic not being a perfect diffuser.

A lever extended from the main shutter arm to a crank and reducing unit outside the room, Fig. 7. This reducing unit was connected to a variable speed motor which in turn was controlled by a Heller electronic control unit. With this driving mechanism, the shutter arm moved as the sine of the angle of deflection of the crank and gave a fairly linear reduction in luminaire brightness. The driving mechanism was reversible by turning a switch on the control unit.

Measured at the book, the illumination level could be held at one value, reduced or increased at a uniform rate, or the rate could be varied. Having available several interchangeable reducing gear units, the illumination could be changed from 220 footcandles down to one-fifth of a footcandle within 5 minutes at the fastest rate to 5 hours at the slowest rate. These illumination values were determined with a Macbeth illuminometer by holding the eye-piece at right angles to the test plate at a distance of about 8 inches, with the test plate in the same position as the book.

A pointer was mounted on the shaft which turned the crank-control of the shutter. A dial scale was placed just back of the pointer. A number of illumination readings were taken as the pointer was moved along the scale as the shutter was opened from the minimum position to the maximum position. These readings were marked on the scale at the appropriate positions of the pointer. With the subject in reading position, the door closed and the shutter control-drive running, the experimenter could readily determine the illumination level at any instant during the experimental session.

Recording of Muscle Action Potentials. — The input stage of this electronic device is a differential amplifier which cancels out the 60-cycle AC produced by surrounding equipment. The differential amplifier leads into a four-stage amplifier which has considerable feedback to give stability. The last stage of this amplifier leads into an integrating circuit, the output of which is indicated on a meter, a recorder and a cathode-ray oscilloscope, Figure 8.

In these studies on the effect of illumination levels on muscle action output during reading, the electrode wires from the subject's headband were plugged into a small switch panel inside the subject's room. A shielded cable led out from this room to the alertness indicator where the experimenter could record simultaneously the meter readings indicating tension level and the pointer position on the illumination scale indicating the illumination intensity.

Recording Eye-Movements as an Indicator of Continuous Performance. — In the present laboratory setup the eye-movements and the tension-level were recorded on two independent electronic systems. One switch panel in the subject's room served for recording the subject's tension level as described in the previous section. Another switch panel served to connect electrodes from the surface of the skin just back of each eye to preamplifiers in a third room in a laboratory. Leads from the preamplifiers were connected to power amplifiers and then to an ink-writing oscillograph which recorded the eye movements continuously.

During the experimental session the experimenter gave verbally the meter readings of the alertness indicator and the scale reading on the illumination intensity control each half-minute over an intercommunication system to an assistant in the third laboratory room. The assistant recorded these readings on the recording tape. Thus, from these records it was possible to read the illumination level, the subject's tension-level and the lines read for each half-minute. The experimental also kept a record of the time, meter reading, and illumination scale reading as he verbally gave these values to the assistant.

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State Capitol Floodlights its Dome

As part of the renovation of the roof area of the Utah State Capitol building, Salt Lake City, installation of new floodlights was in order. Twenty 1000-watt lamps were used in totally enclosed type Alzac reflectors. These are served by individual circuits fed from multi-breaker load centers located near the individual groups of floodlight units. Feed lines run from the basement up the pipe shaft to the roof. The main control switch is on the panel board in the basement.

The floodlighted dome can be seen from all sides of the Salt Lake Valley, even in fog. Photo courtesy of Universal Trade Press Syndicate, New York, N. Y.

Muscle Action Potentials— As Related to Visual Tasks in Industry

By WILLARD ALLPHIN

IN I.E.S. Research Project No. 23, results of which are published on page 182 of this issue, subjects were given an easy book to read in a room having comfortable brightness contrasts. The illumination level could be changed over a very wide range at a rate slower than the adaptation rate of the subject. Thus he was unconscious of changes in illumination, at least for any level above one footcandle.

Project No. 23 showed little change in tension level or reading rate with changes in illumination when reading easy print, but reading small, faded print or yellowed paper did show a strong and direct relation between illumination and reading rate. The tension level rose throughout the latter test, regardless of illumination level.

The present project represents a preliminary attempt to carry the technique outside the walls of the laboratory and investigate some typical tasks in industry. Obviously no such brief excursion can produce definitive results, in view of the complexities of the human organism, the complications of industrial tasks and the difficulties of establishing anything resembling a controlled situation in the factory.

However, it is desirable to determine whether or not muscle action potentials of the type measured in the laboratory can be measured in the field, and to see whether they appear to be related to the visual elements of the industrial task.

Inkwriting apparatus which would operate on the output of the amplifier was not available for field use, so it was necessary to depend upon periodic readings of the meter.

Stenography

Muscle action potentials from the frontalis muscles of a secretary were measured while she was, at various times, taking dictation in shorthand, typing from shorthand, typing from longhand, and typing from typewritten copy.

Method. — The arrangement is shown in Figs. 1a and 1b. Sponge-type electrodes are moistened with salt water and held in place just above the eyebrows. A test circuit incorporated in the equipment permits the resistance between electrodes to be measured at any time, thus insuring that good contact with the skin is maintained.

Indicated tension level goes up instead of down with poor electrode contact or with B battery failure because the meter actually works backward. The circuit is arranged, for reasons best known to an electronics expert, so that a high meter reading means a low voltage from the frontalis muscles and vice versa. A table of coefficients is used to translate the meter readings into microvolts of tension.

The type of response from this subject would have looked something like Fig. 2 if the movements of the needle could have been recorded fast enough.

Since an inkwriter was not available, the observer recorded the principal tension level at 15- or 30-second intervals, ignoring the brief "spikes" or upward and downward swings of the needle.

The lower level of illumination was controlled by adjusting venetian blinds to admit more or less daylight. The upper level was supplied by diffused light from a photoflood lamp placed out of the field of view.

Results. — Fig. 3 shows one of several runs after the subject had become accustomed to wearing the headband. The points marked by x's are actual readings, omitting spikes, and the curve is a moving average. That is, each point on the curve is the average of three values — the one for that time and the one on each side of it.

At 30 minutes, the subject was given an easy book to read, for purposes of comparison.

Discussion. — If the tension level is associated with the cost of seeing, it is evident that this subject was using no more energy under low illumination than under high. However, there was no practical way of measuring her output in this test, and it is perfectly possible that she was producing more work under the higher illumination level. The reading portion of the test being at the same general level would indicate that she was not making heavy demands upon her reserves while typing. This is plausible, since she is an experienced secretary.

Substance of a paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: Sylvania Electric Products Inc., Ipswich, Massachusetts.

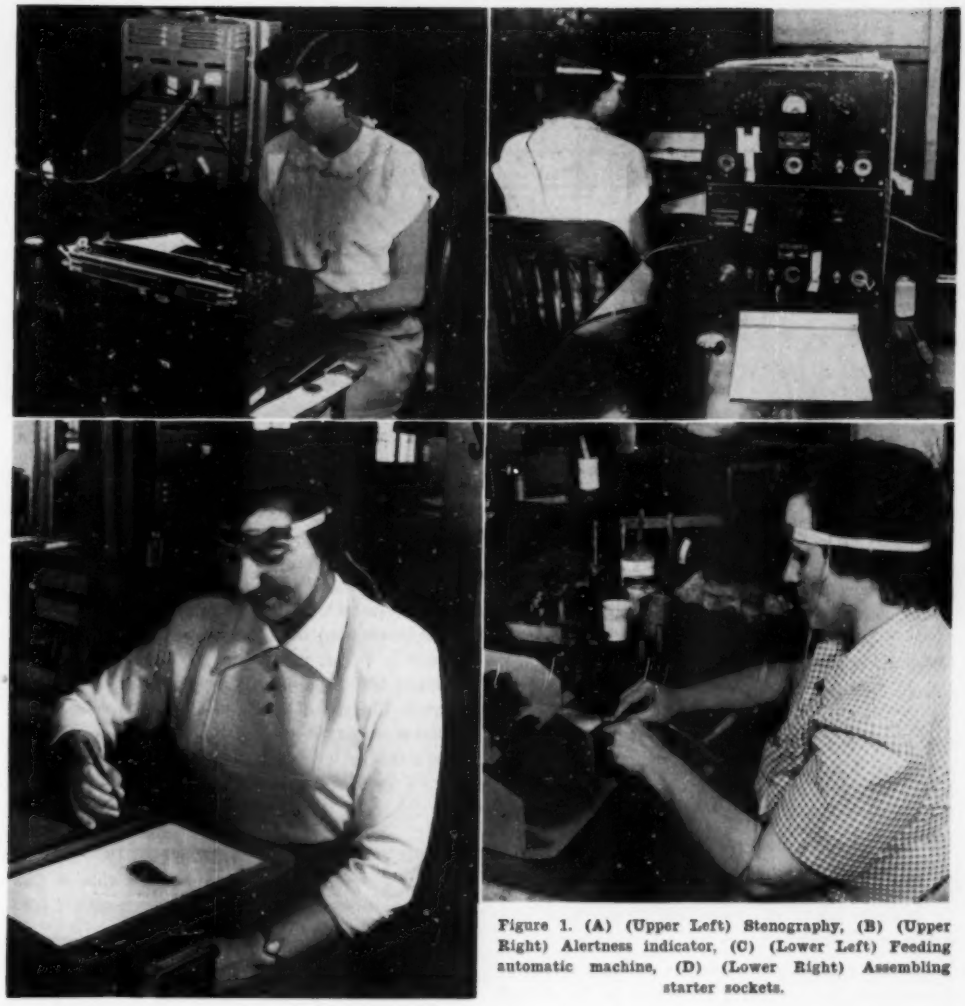
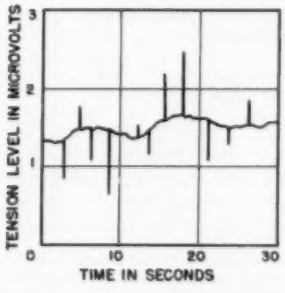


Figure 1. (A) (Upper Left) Stenography, (B) (Upper Right) Alertness indicator, (C) (Lower Left) Feeding automatic machine, (D) (Lower Right) Assembling starter sockets.



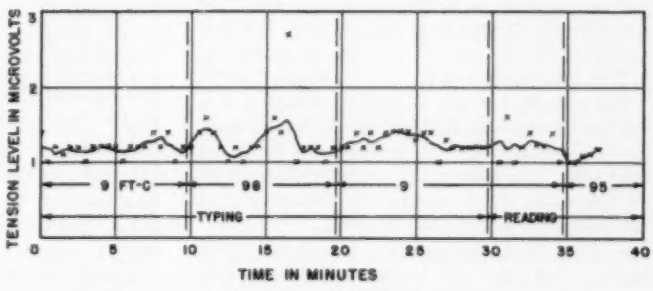


Figure 2. (Left) Freehand representation of typical response in stenography work. Figure 3. (Right) Typical run in stenography work.

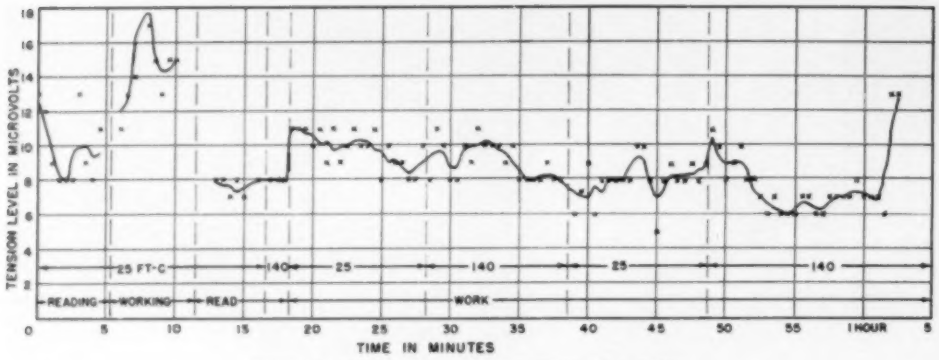


Figure 4. Complete run — feeding automatic machine.

Feeding Automatic Machine

Method. — Fig. 1c shows an operator feeding filament wires (0.00053 inch in diameter) into an automatic machine in an incandescent lamp plant. She picks up a filament with a pair of tweezers, examines it to see that it is straight, and draws it across two toothed rails which move at a rate of 36 filaments per minute.

The lower illumination level represents the least which could be used without switching off overhead general lighting and disturbing others in the factory.

Results. — Fig. 4 shows a run of two hours and seventeen minutes just as it occurred from the beginning. The character of response was similar to that shown in Fig. 2, although the values were higher, and again the spikes were not plotted.

The subject was given a book to read at the beginning of the test and again from 13 minutes to 18 minutes while the lamp-making machine was being readjusted.

The irregular tension level in the first two five-minute periods and the high values in the second were probably due to unfamiliarity with testing and nervousness about the headband. Note that a higher illumination level did not affect the tension level at 16½ minutes but that the industrial task at 18½ minutes did produce a higher level.

The contact resistance was checked from time to time and found to be satisfactory; but at one hour, two and one-half minutes, it was found to be unduly high. The subject had probably disarranged the electrodes. Good contact was reestablished at one hour, nine and one-half minutes.

A relief period longer than the customary 10 minutes was taken, for reasons not directly connected with the test. Note that when the subject resumed work, the tension level was at its lowest values. It then went into a slow rise, although this rise could have been merely advance warning of B battery failure which occurred at about two hours, sixteen minutes.

Discussion. — Perhaps if it had been possible to provide a much lower level of illumination, such as three to five footcandles, the tension level would have increased with low illumination. However, it must be pointed out that this operator has done similar work for a number of years and that the speed of the machine is not within her control. It is quite likely that she is not being "pushed" to perform the task and could actually work considerably faster if the machine could be speeded up.

Assembly

Method. — The operator shown in Fig. 1d assembles fluorescent starter sockets, working as fast as her abilities and the quality requirements permit. The sequence is as follows:

1. Place plastic shell on bench.
2. Insert two brass fingers in shell.
3. Dip first wire in flux and place end on brass finger.
4. Solder first wire to finger.
5. Dip second wire in flux and place end on brass finger.
6. Solder second wire to finger.
7. Place cover on shell.
8. Place first rivet and hammer it.
9. Place second rivet and hammer it.
10. Put finished socket aside.

Operations 4 and 6 are the critical ones, visually. The soldering iron, like a spot welder, descends upon the work when the operator steps upon a foot pedal. Just before stepping on the pedal, the work must be approximately centered under the iron. The location is corrected when necessary, while the iron is descending. Actually, it all seems part of one smooth motion, but to anyone studying the

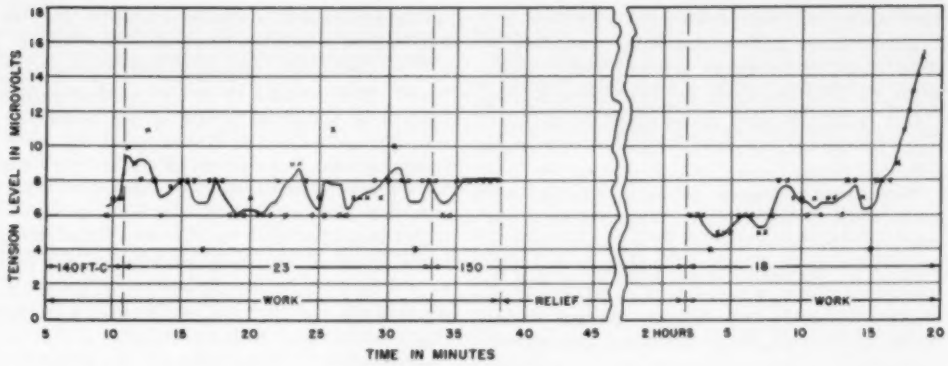


Figure 4 (Continued).

cycle, it is evident that the seeing requirements are considerable in locating the point accurately.

Results. — Either because of the particular subject or the different nature of the task, the responses were quite different from those in the previous tests. There was no pattern such as in Fig. 2. The needle was constantly in motion and it was evident that its movements were closely tied to the work of the operator.

For this reason, it was decided to simulate an inkwriter by recording all of the swings in tension level in terms of the work cycle. A single observer was unable to do this because the operator was performing at the rate of nearly three cycles per minute, but two observers were able to accomplish the result. One watched the operator and whispered "read" at each significant point of the cycle, while the other watched the meter and wrote down the reading without looking at his writing.

The footcandle levels were the result of turning the general lighting on and off, the lower level representing daylight alone.

The first runs of a day are likely to be rather irregular, such as those in Fig. 5. Part of the irregularity is very probably due to nervousness of the operator at being tested. Also, certain high points are known to be due to a shift of head or body position, sometimes when the operator looks

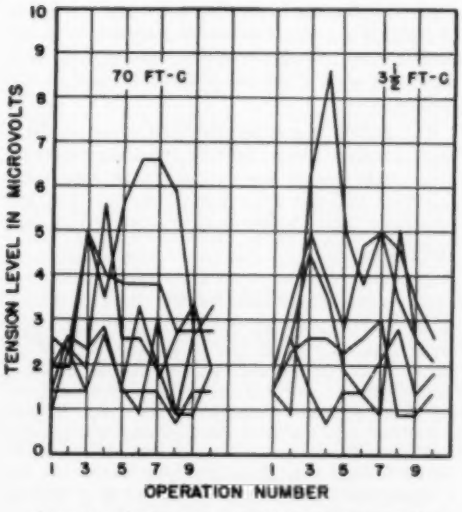


Figure 5. First runs — assembling starter sockets.

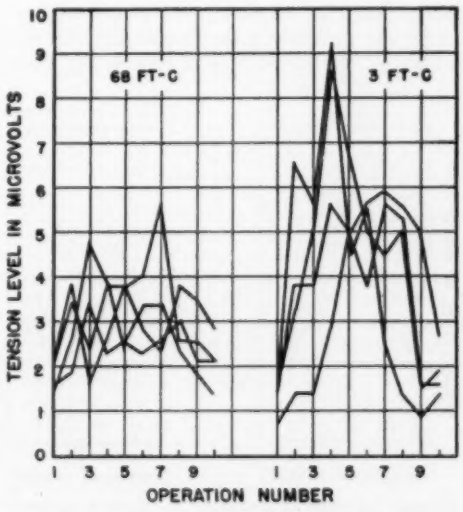


Figure 6. Later runs — assembling starter sockets.

up in answer to a shout from a fellow worker.

When things have settled down somewhat, a definite pattern emerges as in Figs. 6 and 7. Even when all data are used, including some known "wild" points, the averages are as shown in Fig. 8. These cover 17 runs at high illumination and 16 at low.

Note that the highest points of tension level occur when the most critical seeing is done. In many of these runs and in others where tension levels were not measured, the length of the cycle was timed with a stop watch. The average of all 48 runs measured was 20.9 seconds per starter socket under high illumination and 24.1 seconds under low, an increase of 15 per cent.

Discussion. — It has been pointed out that in the previous test, the operator may have been held back from her highest possible performance by the speed of the automatic machine.

Here, in a task where the work is well standardized and the operator is not limited by the speed of a machine, the tension level reflects the visual difficulty of the task. Even if it be argued that the peaks at operations 4 and 6 are due all or in part to the muscular work of stepping on the pedal, we still have the fact that a higher level was reached under low illumination.

Conclusions

In an investigation of this nature, when results are obtained which would be expected from a commonsense viewpoint, such results tend to establish the validity of the criterion. This is the case with the assembly job where it seems obvious that the visual cost should be higher under very low illumination. The higher tension level found under low illumination is a strong indication that the tension level is associated with the cost of seeing.

It is possible that with inkwriting equipment to record rapid changes in tension level and with integrating equipment to sum up the values over some such period as one minute, significant differences might also be found within the first two tasks for different illumination levels. Again it is possible that differences would have been revealed if it had been feasible to provide lower illumination levels. However, any really quantitative work will have to be performed in the laboratory, because of the difficulty of controlling conditions in a factory without interfering with production.

Although the first two tasks did not show a correlation between lighting and tension level at the lighting levels involved, it was thought desirable to include the results in this report for the bearing they may have on future researches, and for the worthwhile discussion which may be elicited at the time of presentation.

The further confirmation of the criterion and its broad use as a tool in determining optimum illumination levels, brightness patterns, etc., will be a laboratory job. Further excursions into the field will be desirable from time to time, however, in order to determine the sorts of tasks which lend themselves to the technique.

The tentative conclusion at this point is that muscle action potentials, as measured by the Tufts-Navy Alertness Indicator, are a criterion of the physiological cost of seeing.

Among the many other investigations which need to be made are the study of optimum illumination levels for various industrial tasks and the effect of position and magnitude of a glare source in the field of view. Besides supplying useful data, such work will tend to further confirm or disprove the criterion.

The author wishes to thank Dr. John L. Kennedy, Director of the Applied Psychology Laboratory, Tufts College, for the loan of the equipment, and Dr. Kennedy, Dr. Roland Travis, and Dr. Leonard C. Mead of the same laboratory for advice and assistance.

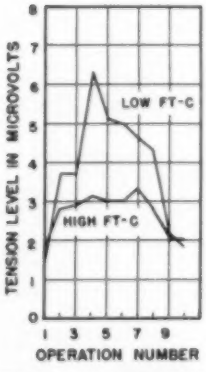


Figure 7. Averages of data in Fig. 6.

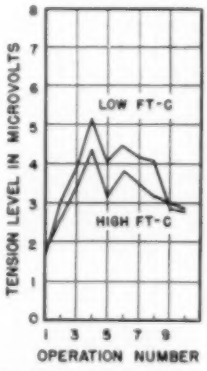


Figure 8. Averages of all data — assembling starter sockets.

DISCUSSION

W. A. RYAN*: In commenting on Mr. Allphin's very interesting research, I should like to add only that we are pleased to see that his results bear out our own experience in many respects. We have used similar methods of recording muscle potentials during work upon a task in which output rate is controlled (a simulated inspection or proofreading task[1]). We have used three different experimental designs to discover the effects of varying illuminations over a range from 2.5 to 50 ft-c. So far, we have found no

*Cornell University, Ithaca, N. Y.

effects of illumination level upon muscle potentials developed during performance of this task. In these studies we have used substantial numbers of subjects and in some cases repeated the observations for the same subject over periods of several days.

On the other hand, we find that changing the difficulty of the task only very slightly has a clear-cut effect upon the potentials developed. The introduction of severe glare also has significant effects, although not so universal as the effects of the difficulty of the task. We are now running an experiment to find the effects of sudden changes in illumination level, in order to increase the severity of any effects it may have.

Our recording technique differs from that used by Mr. Allphin in that we record from three or four bodily areas simultaneously, our amplifiers are flat from about 30 cycles up, and we integrate electrical activity over longer periods of time — as long as we wish. So far we have not found any particular advantage of recording from the head region as compared with other areas such as the shoulder or upper arm. In fact, one of our recent series upon the effects of difficulty of task showed less significant results from the forehead area than for either the shoulder or upper arm.

ERNST WOLF*: Three experiments are presented in which muscular action potentials were recorded during performance of a visual task, (a) stenographic work, (b) feeding filaments into a machine, and (c) assembling starter sockets. The tasks are performed under illuminations varied for certain working periods from 5 to 150 footcandles. Unfortunately not the same levels of illumination were used for the 3 tests, but set arbitrarily. Performances (a) and (b) do not yield any recognizable effect on muscular potentials in relation to illumination, whereas a rise in potential level is clearly indicated in (c) when for a particular kind of work accuracy is required which may make increased demands on the visual apparatus. Our present knowledge on visual fatigue is still very sketchy. It seems that the potential reserves for visual performance are extremely great, and that therefore the estimation of "effort" or "cost of seeing" is rather hard to make. Any attempt therefore of obtaining actual measurements pertaining to the cost of seeing is very valuable, and work of this type should be greatly encouraged, and continued.

According to measurements on visual acuity, and intensity discrimination we know that the visual acuity function as well as the intensity discrimination function rises rapidly to a maximum, and that further increases in brightnesses improve visual resolution only little. Most of the brightnesses employed during the tests reported here are high enough so that no particular demands are made on visual resolution. If therefore no effects on the potential levels are noticed in (a) and (b) this need not astonish us. It would be very likely that with a further brightness reduction effects on the potential levels would become apparent. In (c) the demands on accommodation, and convergence may be responsible for the potential changes even at the brightness levels used during these tests.

The visual cues used in reading, typing, and feeding of filaments into a machine are probably large enough so that no maximal visual acuity is required at any of the various brightness levels, and therefore visual fatigue might be rather slow, and not be recognized during immediate measurements.

Considering the apparently very great reserves for visual performance under stress, it seems questionable, whether the time interval for observation was long enough. It might be conceivable that the demand on seeing might be better recognized, if the recording of action potentials were continued over longer times. Also repeated tests on the same subjects should be made. In judging the demands on the visual mechanism it seems that the immediate recording during performance of a visual task is not enough, but that concentration at work might prevent the recognition of cost, while a prolonged observation possibly beyond the actual period of work might reveal fatigue effects.

GLENN A. FRY*: Mr. Allphin's investigation has provided useful information about the measurement of muscle action potentials in the frontalis muscles. He has succeeded in showing that usable measurements of these potentials can be obtained from a person engaged in an industrial task and that these potentials are related to the visual elements of the task. Although the results are more suggestive than final, they constitute justification for further effort in the same direction.

Just what relation contraction of the frontalis muscles has to seeing is not known. A contraction of these muscles as a result of an effort to see may be a "spill-over," but, on the other hand, the observer may have learned to use these muscles when he makes an effort to see without being aware of manipulating these specific muscles. In this event, contraction of the frontalis muscles would have to serve some useful purpose such as giving a mechanical advantage to the muscles which control the position of the eyeball or it would have to produce some change in the structure of the eye which would be of assistance in focusing the eye. Studies of the type carried out by Mr. Allphin ought to stimulate interest in this problem.

We need to consider very carefully in what sense contraction of the frontalis muscles is a measure of the physiological cost of seeing. If physiological cost includes the cost of carrying out the primary act, then it is a measure of physiological cost since the contraction of the frontalis muscles is certainly a part of the primary act. The term physiological cost also includes effects on the subsequent performance of the same function or other functions. It might refer, for example, to the effect of using the eyes in the morning, upon the performance of a task late in the afternoon or on a subsequent day. It might refer to the length of time a given task can be performed without decreasing the speed and accuracy or to the development of fatigue or symptoms of eyestrain. It might refer to more permanent and more latent effects upon vision and health such as the development of squint, nystagmus, amblyopia, glaucoma, cataract, abnormal posture, or an increased susceptibility to heart attacks which may not occur until twenty or thirty years later.

Actually we do not care what it costs to see so long as we have the money to pay the bill, and it does not make any difference if part of the cost is hidden as in the case of the activity of the frontalis muscles, just so long as we have enough loose money lying around to pay that bill also. What we are concerned about are the costs which do not show up until later, which we cannot afford to pay and which may eventually wreck us financially.

[1] See reference 9 in Mr. Allphin's paper, and a forthcoming article in the *American Journal of Psychology*.

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* School of Optometry, Ohio State Univ., Columbus, Ohio.

DOMINA EBERLE SPENCER*: For many years the Illuminating Engineering Society has been searching for a quantitative method of assessing the effect of quantity and quality of a lighting system. But it is a very difficult task to prove that we can see better and more comfortably under good lighting than bad. We all feel certain that there is something there — an important and significant difference, but it has appeared nearly impossible to find a suitable measure of it.

Today, as the first fruits of the I.E.S. Research Fund, it appears that there are two methods of attack which at least show some promise.

(1) The first of these is the method of measuring muscle action potentials or alertness, which has been developed by the Tufts psychologists and has been presented and applied so ably by Mr. Allphin.

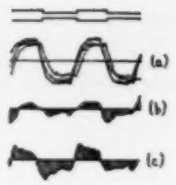
(2) The second is the method of measuring and recording displacement, velocity, and acceleration of the eyeball, as developed by Dr. Lion of the Massachusetts Institute of Technology. To give you an idea of the kind of thing Dr. Lion has found, I refer to the illustration (right) giving some experimental results. He has tested the rather unusual task of attempting to follow two alternately flashing lights, 90 degrees apart at a rate of 120 to 150 changes per minute. It will be noted that the general pattern of the eye motion is repeated. The aspect of these eye motions to which Dr. Lion has given attention is the second derivative of the displacement. He finds that the peaks of the acceleration curve remain of about the same amplitude even when the subject is quite fatigued. And making two rather gross assumptions: (1) that the force exerted by the extrinsic muscles of the eye is directly proportional to the acceleration of the eyeball and (2) that "fatigue" is equal to the decrement of force exerted by muscles, he concludes that there is no "fatigue" of the extrinsic ocular muscles.

But none of us should be surprised at these results. Dr. Luckiesh has long told us that people can force themselves to perform visual tasks under very adverse conditions.

I propose a different evaluation of Dr. Lion's results. Inspection of the oscillograms shows that the eye motions themselves change markedly under adverse visual conditions. Thus, when rested or when working in an ideal visual environment, the eye will perform a given visual task with precision and with a minimum of unnecessary motions. But when the eye tries to see under adverse visual conditions or when a sense of fatigue is experienced, the motions become much more complex. The illustration shows the oscillograms in Dr. Lion's flashing light test. Curve A is taken at the start of the test, B after 5 minutes, and C after 10 minutes. As fatigue sets in, the departure from optimum eye movement increases. The second curve shows the difference between A and B while the third shows the difference between A and C. It will be noticed that the departure from the optimum motion is about twice as large at 10 minutes as after 5 minutes. The general conclusion is that when the sensation of fatigue is experienced, the motions of the eye differ greatly from the simple pattern that is observed under ideal visual conditions.

In these variations of patterns of eye motions of Dr. Lion and in the varying alertness patterns of Mr. Allphin, we have the nucleus of a significant advance in illuminating engineering. If we can correlate these measurements with the specification of the visual environment, real progress will have been made.

The next step in both researches should be to test the eye motions and alertness potentials in a controlled luminous environment, and for some typical practical visual tasks. The varying responses should be studied first as quantity of light is varied with a uniform surround and then as direct and reflected glare sources are superimposed on the uniform field.



Oscillograms for flashing light test.

These projects are not completed. They have barely begun. These preliminary reports are merely the go-ahead signal for a more elaborate research. The work should be completed in collaboration with an illuminating engineer who can design and control the luminous environment. A correlation should then be developed between alertness potentials, eye motions, and the luminous environment. It is to be hoped that the I.E.S. Research Committee will realize the basic importance of this work to the Illuminating Engineering Society and will find the funds to sponsor the completion of both of these projects.

M. E. BITTERMAN*: For several years I have been of the opinion that muscular tension measurements provide the most promising avenue of approach to the evaluation of the physiological cost of visual work. Laboratory investigations reveal a number of difficulties which must be overcome before the technique can be put to practical use, but these difficulties do not seem insurmountable. The principal problems with which we have been confronted in the laboratory are twofold:

(1) *Control of performance.* A worker may react to the introduction of difficult seeing conditions in many ways, depending upon his motivation. He may maintain the previous level of effort expenditure and allow performance to deteriorate, or, he may maintain the previous level of performance at the expense of additional effort. It is also possible that *both* output and effort may change. Often, for example, a worker will *overcompensate* for the difficulty, with the result that both output and effort will rise. In other cases, the worker may only partially compensate for the difficulty so that performance falls off despite the fact that there is some increase in effort. For this reason, as Mr. Allphin recognizes, changes in muscular tension can only properly be evaluated in relation to changes in performance.[1]

It must be recognized that, in attempting to validate muscular tension as an index of effort, we are faced with the task of correlating our tension measures with something that cannot itself be measured, but only *inferred*. For this reason it is necessary to arrange the conditions in such a way as to make possible the clearest inference concerning effort changes. As far as I have been able to determine, the optimal conditions for this purpose are those in which performance remains constant following the introduction of an obviously inadequate working environment. If the change

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introduced can be assumed to increase the difficulty of the task, and if, despite this change, performance is maintained, then it can be assumed that effort has increased. If the change in working conditions is accompanied by a significant rise in muscular tension, we have some basis for assuming that muscular tension may be directly correlated with effort level. Of course, if the worker overcompensates — that is, increases his output in the face of conditions known to be inadequate — effort can also be assumed to increase, but since muscular tension is also affected by the level of overactivity, it is impossible to attribute any tension increments found under these conditions to effort expenditure *per se*. To illustrate the distinction between the effort level and level of overt activity, we may consider the case of two workers performing an identical inspection task. Worker A is assumed to be working at a much higher level of effort than is worker B, but worker B is required to record his observations while worker A is not. The muscular activity required for recording may produce a higher overall tension level in worker B despite the fact that his effort is lower. Such considerations have led us, in our laboratory investigations, to work with controlled-rate tasks — tasks which permit variations in effort but which restrict the possibility of variation in output.[2]

(2) *Variability.* In the course of testing many subjects, we have found tremendous variability in tension level, not only from person to person, but also in the same person from time to time. To some extent, as Mr. Allphin reports, this variability may be traced to apparatus difficulties, but I doubt that all of the variability encountered may be assigned to this source. There is reason to believe that physiological conditions unrelated to variables under investigation may be in great part responsible. Consequently it is necessary to work with muscular tension to make many repeated determinations and careful statistical analyses of the data before conclusions with respect to the influence of any given variable are drawn.

I cannot but be impressed with the qualitative similarity between the results which Mr. Allphin has obtained in his field studies and those which we have obtained in comparable laboratory investigations. In both circumstances negative results are liberally admixed with positive ones, but in both circumstances, too, the positive findings are convincing enough to suggest that continued study will yield important results, both practical and theoretical. Mr. Allphin's valuable contribution also suggests that the difficulties which confront us are substantially the same under both laboratory and field conditions, and that once suitable techniques have been worked out at the laboratory level we may hope to be able to apply them directly to the solution of practical problems.

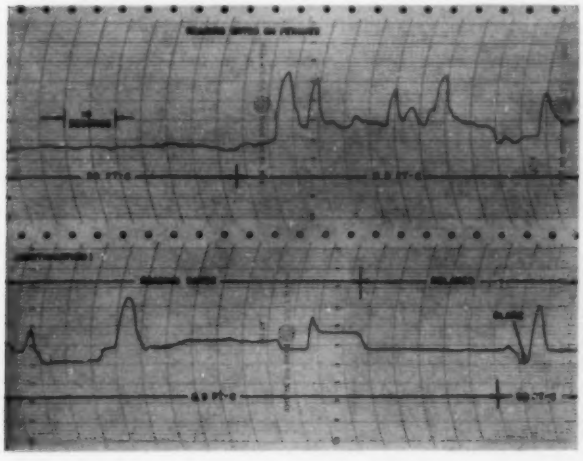
[1] Much of the confusion over the validity of blink-rate has stemmed from the failure to give proper attention to correlated performance changes. See C. L. Wood and M. E. Bitterman: A proposed resolution of the controversy over frequency of blinking as a measure of effort in visual work, *Amer. J. Psychol.*, October 1950.
[2] T. A. Ryan, C. L. Cottrell and M. E. Bitterman: Muscular tension as an index of effort: The effect of glare and other disturbances in visual work, *Amer. J. Psychol.*, 63, 1950, 317-341.

WILLARD ALLPHIN*: The author wishes to thank the discussors for their friendly and helpful comments. The point raised by Prof. Ryan about the best location of electrodes is one on which there seems to be disagreement among applied psychologists. Those at Tufts prefer the single location, but it is certainly a question which would bear further study.

Dr. Wolf suggests that the observation time was not long enough for fatigue to develop. It was emphasized in the paper that cost of seeing was being considered as separate from fatigue. It is, of course, likely that if we learn to measure cost on a moment-to-moment basis and then extend the researches to longer periods of time, we shall find fatigue to be influenced by cost, and vice versa.

I do not agree with Dr. Fry that, "We do not care what it costs to see as long as we have the money to pay the bill." Why not spend as little as possible for effective seeing and have more "money" left over for other activities?

*Author.



Tension level of subject reading dates on old pennies, except in portion marked "Relaxed." Glare source introduced at point marked by arrow and removed at peak of curve.

After the paper had gone to the printer, a recording photoelectric potentiometer became available and was used as a partial check on the earlier work. A photograph of an actual chart is included here because of the bearing it has on some of the points raised by the discussors. The task was reading the dates on old pennies and, as a matter of interest, the subject whose chart is shown here is the secretary who showed no correlation between illumination and stenography in the original paper (Fig. 1A).

The subject was reading dates and calling them out during the entire period covered by the chart except for the last portion marked "relaxed." Note that at 50 footcandles, there was no effect on the tension level, but that at 0.5 footcandles there was a peak of tension for each date read. These peaks were not caused by the jaw muscles in speaking, because each occurred while the subject was peering at the coin, just before she spoke.

When the subject relaxed at 0.5 footcandles, the tension level was steady but somewhat higher than when reading dates under 50 footcandles. Returning to 50 footcandles lowered the tension but it rose to a peak again when a strong glare source was momentarily introduced into the field of view at the point marked by the arrow on the photograph of the chart.

An Engineering Drafting Room Installation

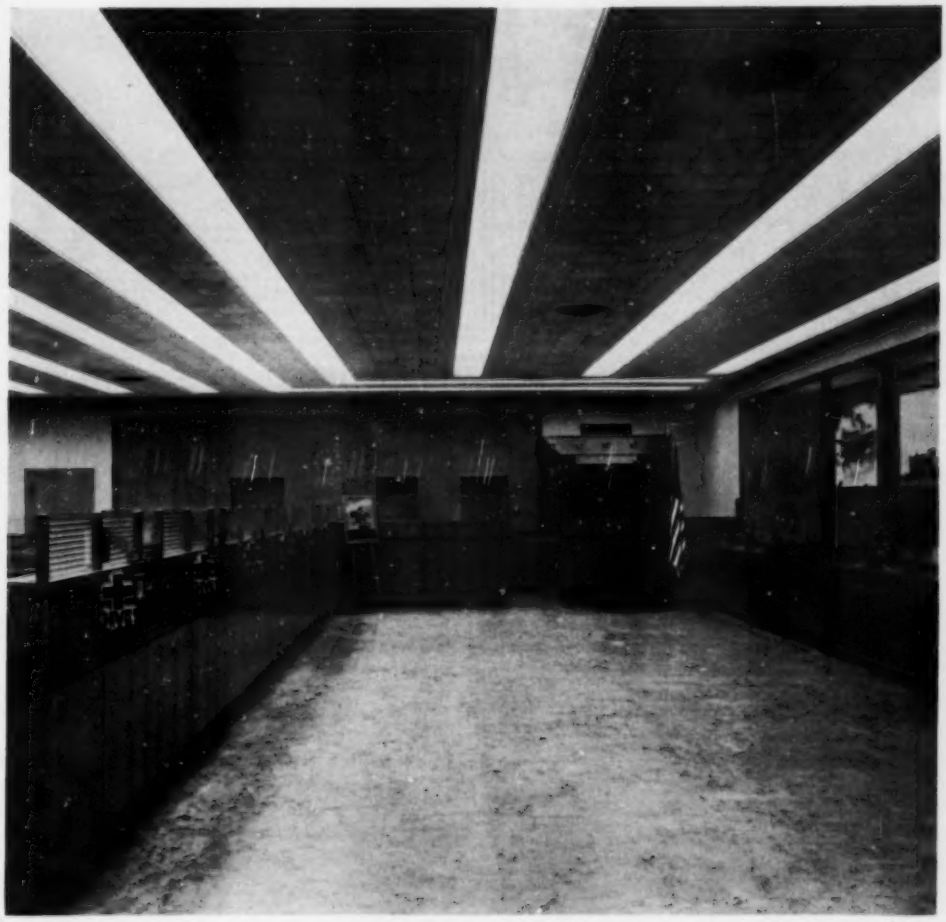
Engineers in the drafting department of the Harley-Davidson Motor Company, Milwaukee, Wisc., now work under initial levels of over 100 footcandles, with disturbing shadows from instruments over working surfaces minimized. Some 2300 square feet of the rectangular room are illuminated by 79 4-foot sections, each comprised of four 40-watt fluorescent luminaires lamped with 4500-degree soft-white tubes.

Design of the interlocking louvers of the all-white finish luminaires permits 45-degree cut-off, 20 per cent of the illumination being thrown against the ceiling and 80 per cent directed downward.

This picture was taken at one second exposure with regular press film. Camera was stopped down to f.32. No additional illumination was used. Photo courtesy of Harley-Davidson Motor Co., Milwaukee, Wisc.

Lighting a Branch Banking Office

LIGHTING OBJECTIVE: To provide a high level of illumination with low brightness ratios.



Installation at Manufacturers and Traders Trust Co., Airport Plaza, Cheektowaga, New York; architects: Hudson & Hudson, Buffalo, New York.

General Information: This area measures 60 x 40 feet with an 11-foot ceiling. Surface characteristics are as follows:

walls	blue plaster	50% RF
wood paneling	light oak	40% RF
ceiling	acoustic tile	65% RF
floor	tan asphalt tile	30% RF
work surfaces	tan linoleum	30% RF

(over)

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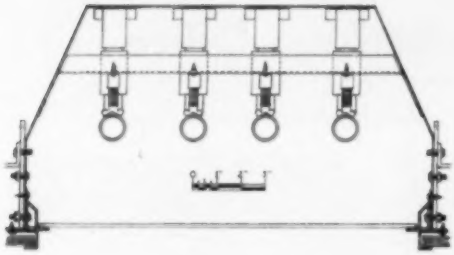
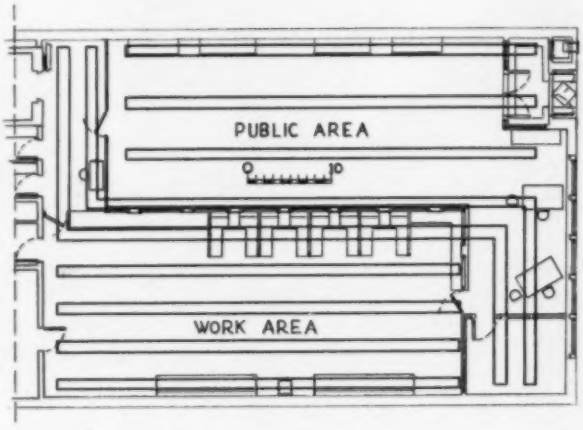


Cross section of troffer (left)

Plan view (below)



Installation: Cold cathode troffers are arranged to produce the highest levels of illumination on tellers' counters and clerks' desks. The 16-inch-wide troffers have 4 rows of 25 mm cold cathode lamps, half white and half soft white, except 2 rows of troffers over the public circulation area which have 2 rows of lamps each. Lamps operate at 100 ma. Total length of troffers is 520 feet (glass area = 700 square feet) with 1824 feet of cold cathode tubing. Total load is 13.2 kilowatts or 5.5 watts per square foot.

Average illumination and brightnesses after one month of operation were as follows:

tellers' counters	85 ft-c	troffers	
deal plates	75 ft-c	0 degrees	290 ft-L
ledger desks	75 ft-c	45 degrees	250 ft-L
circulation area	50 ft-c	ceiling	12 ft-L
public check desks	35 ft-c	wall	
		plaster	12 ft-L
		wood panel	12 ft-L
		floor	25 ft-L
		tellers' work surfaces	24 ft-L

Lighting equipment supplied by Eastern Sign Company, Buffalo, New York.

Lighting data submitted by Niagara-Mohawk Power Corp., Buffalo, New York as an illustration of good lighting practice and to aid in the design of similar installations.

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Uniformity of Illumination in Highway Lighting

By A. E. SIMMONS
D. M. FINCH

THE STATUS of the art of highway lighting is reaching a stage wherein it is desirable to re-examine some of the design procedures that are used. Many state highway departments and local government agencies are busily engaged in very extensive new highway construction programs, most of which provide for a limited amount of lighting — at least on sections and locations where it can be justified on a "safety" basis. However, this limited amount is costing as much as $50,000 per mile in many cases. The lighting design problem is usually one of economics and cost as well as illumination engineering. In other words, the problem is: How can one get the best job with the money available? Each engineer seems to have his own ideas about what the "best" job is. It is this subject of quality that we would like to review.

The American Standard Practice for Street and Highway Lighting[1] offers the highway lighting design engineer an excellent source of design criteria. The background information contained in this publication has been developed over a long period of time and has evolved from principles first published in 1928. The basic material is sound and well established by years of field experience. Most highway lighting designs are based upon these recommendations, so particular attention will be directed toward the design practices recommended therein. The references in this discussion are to the latest American Standard Practice for Street and Highway Lighting approved September 30, 1947, sponsored by the I.E.S., and hereafter referred to as the Standard Practice.

However, since the publication of the above Standard Practice, newly designed luminaires, and higher intensity light sources have become available. When these new luminaires and high intensity light sources are used it has become increasingly difficult to reconcile the results of recommended design procedure with the known requirements for good visibility.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Authors: Assistant District Engineer, Division of Highways, California Department of Public Works and Associate Engineer, Institute of Transportation and Traffic Engineering and Associate Professor of Electrical Engineering.

There is general agreement on the desired end result of good highway lighting. In the publications of the I.E.S. as far back as 1937 there are lighting recommendations indicating general agreement that good visibility at night can be attained only by having adequate pavement brightness with good uniformity, together with reasonable freedom from glare.[2]

One of the purposes of this paper is to analyze the present recommended design procedure and point out several inherent factors that are in conflict with these recognized requirements of good visibility. Also, it seems desirable to have some specific definition of what constitutes adequate pavement brightness and good uniformity. To this end several suggestions for minor modifications to the existing Standard Practice are offered. These are intended to permit a more accurate specification of the lighting characteristics on extended sections of lighted highways.

A survey of the literature[3, 4, 5, 6, 7, 8] reveals that a tremendous amount of effort and thought lies behind the design procedure given in the Recommended Practice.[1] All these fundamental studies of highway lighting show that a satisfactory prediction of the quality of the lighting requires a complete knowledge of all the physical factors including:

1. the photometric characteristics of the luminaire (light distribution and intensities),
2. the mounting arrangements, and
3. the roadway layout and roadway surface properties.

The last is still the most incomplete quantity.

In many instances a lighting design engineer cannot spend the time required to use all of the basic data in making his layout. In other instances he may not have the data immediately available. In any event he finds that the technique of using the presently available material is cumbersome. It would seem desirable to have a simple method whereby the designer could quickly get all the essential design information for a particular arrangement of lighting units, mounting height, and roadway width. The desirable quantities are: (1)

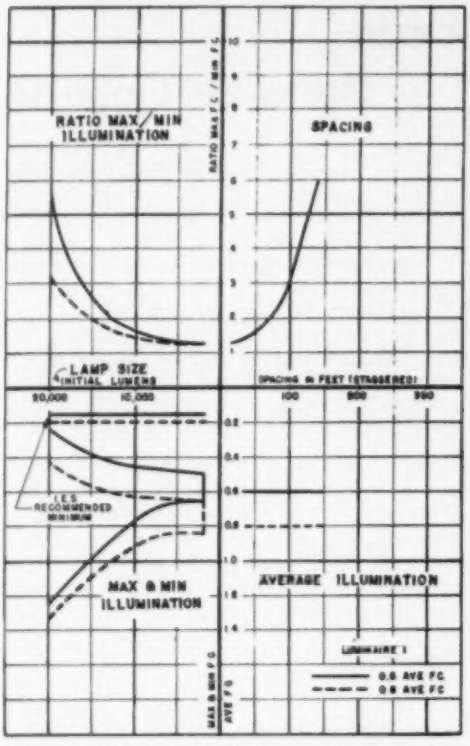


Figure 1. Luminaire performance curves. Mounting height 30 feet. Roadway width 102 feet. A.S.A. Type IV. Average illumination method.

minimum illumination, (2) maximum illumination, (3) average illumination, (4) ratio of maximum to minimum illumination, and (5) spacing to use for any required illumination and lamp size. It is also very desirable to know how the brightness of the roadway will vary over the surface, but until such time as more data are available on road-surface reflectances it is not possible to predetermine brightness ratios with accuracy. It can be demonstrated, however, that if illumination ratios are satisfactorily controlled, the brightness ratios will generally fall within acceptable tolerances.

It should be emphasized that uniform illumination must be accompanied by reasonable freedom from glare in order to insure comfortable and adequate visibility. Therefore, extreme care must be exercised in luminaire design and layout to avoid high brightnesses at high angles of elevation. Close spacing with high mounting height and medium sized sources are indicated rather than wide spacing with large sources. Increased discomfort and loss of visibility would result from such bright sources in the field of view and may nullify all gains due to uniform illumination.

A method of quickly laying out and evaluating typical installations is presented in the following paragraphs. Emphasis is given to considerations of uniformity since it is believed that this is of primary concern in any good highway lighting layout. All the essential data are presented in a series of graphs. Each series is for a particular luminaire and gives all the required information for the unit when used under the most common conditions. If the data for the various luminaires were furnished in this form by the manufacturers, a direct evaluation of the performance characteristics for each luminaire would be possible. The design engineer would be relieved of the repetitious type of computation and could directly select a type of luminaire to fit the conditions under consideration. For the initial calculations, or for any non-standard

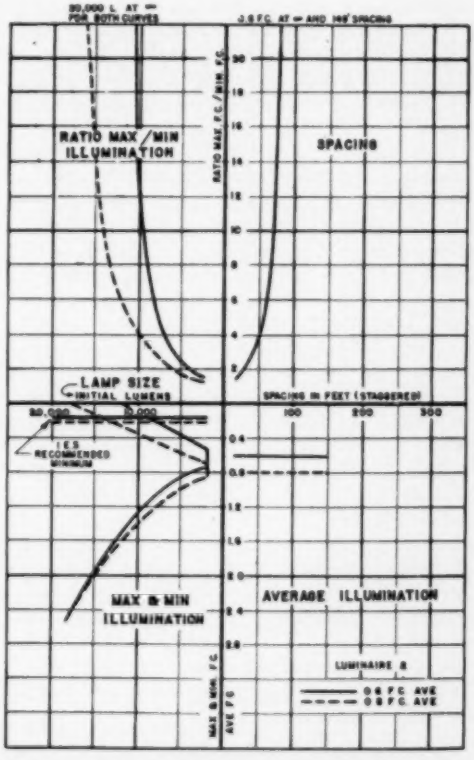


Figure 2. Luminaire performance curves. Mounting height 30 feet. Roadway width 102 feet. A.S.A. Type III (shielded). Average illumination method.

job, it would still be necessary to have an iso-candle diagram for the luminaire.

In order to reduce to a minimum the many variables that are involved in an analysis of this kind, the types of luminaires selected for study have been reduced to two: (1) a modern Type IV reflector luminaire, and (2) a modern Type III shielded reflector luminaire. It is generally agreed that these two types are the most important in highway lighting insofar as light distribution and glare are concerned.

Three typical roadway widths commonly used in modern highway design have been included in this study, namely a 2-lane, one-way ramp, 28 ft wide; a 4-lane, divided highway, 70 ft wide; and a 6-lane divided highway, 102 ft wide. Typical sections of these highways are shown in Fig. 14.

It will be recalled that the recommended design procedure involves the selection of an *average* illumination value from Tables IV, V, and VI of the Standard Practice[1] with certain modifications depending on the pavement reflection factor and

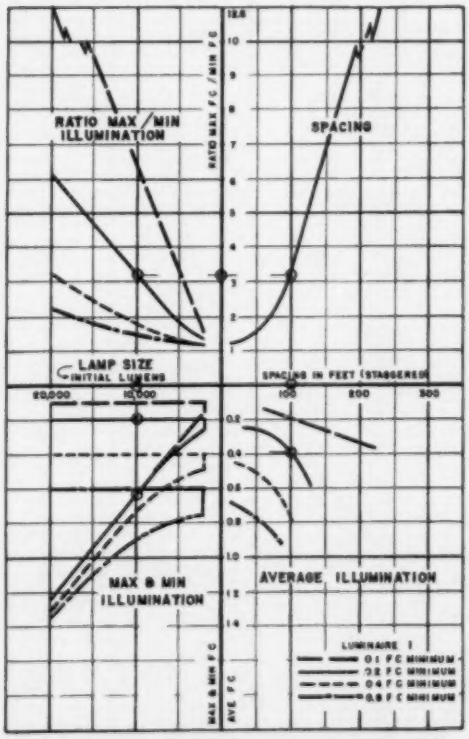


Figure 3. Luminaire performance curves. Mounting height 30 feet. Roadway width 102 feet. A.S.A. Type IV. Minimum illumination method.

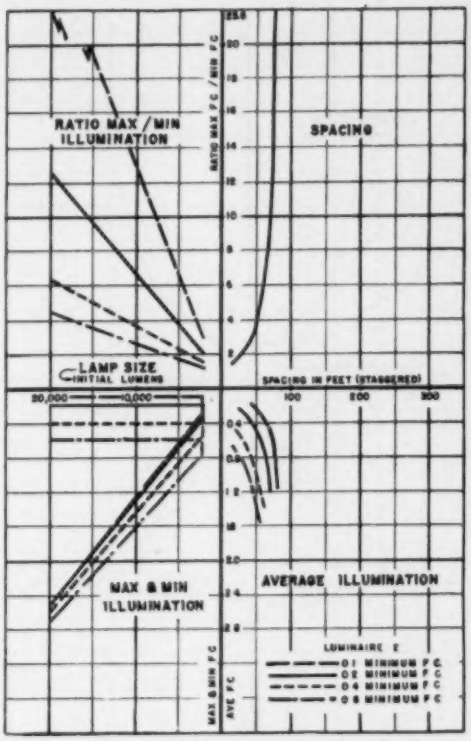


Figure 4. Luminaire performance curves. Mounting height 30 feet. Roadway width 102 feet. A.S.A. Type III (shielded). Minimum illumination method.

luminaire depreciation. This value of average illumination, together with the utilization factor of the luminaire, the initial lamp lumens, and the width of the street determines the recommended luminaire spacing. For example:

$$\text{Luminaire Spacing} = \frac{\text{Lamp Lumens} \times \text{Coefficient of Utilization}}{\text{Average Footcandles} \times \text{Width Street}}$$

Typical Problem:

when { Coefficient = 0.443; Ave. Illum. = 0.6 ft-c; Width Street = 50 ft }

For a 4,000 Lumen lamp

$$\text{Luminaire Spacing} = \frac{4000 \times 0.443}{0.6 \times 50} = 59 \text{ feet}$$

For a 20,000 Lumen lamp

$$\text{Luminaire Spacing} = \frac{20{,}000 \times 0.443}{0.6 \times 50} = 295 \text{ feet}$$

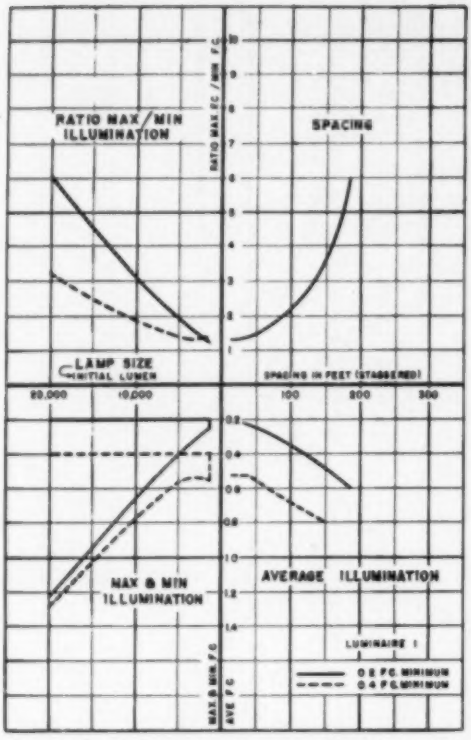


Figure 5. Luminaire performance curves. Mounting height 30 feet. Roadway width 70 feet. A.S.A. Type IV. Minimum illumination method.

Obviously nothing in this procedure indicates the uniformity of illumination falling on the pavement. It is also obvious that the luminaire spacing given by this relation varies directly as the size of the light source. Thus the spacing for a luminaire equipped with a 20,000-lumen light source would be 5 times that of the same luminaire equipped with a 4,000-lumen light source. Even the most optimistic highway lighting engineer will admit that with only this much information available, it would be very difficult to make an intelligent prediction of the effective visibility of roadway obstacles under these two extreme conditions. Yet on several occasions it has been noted that highway lighting design engineers have done just this, stating that they were faithfully following A.S.A. design procedure.

It is true that the Standard Practice[1] states that the minimum pavement illumination should not be less than one-fourth of the recommended average illumination, but this would seem to be very inadequate and the method by which this condition is obtained is not outlined. This statement also implies that the maximum would be considerably greater than the average value. The total variation is an important consideration and will be treated in detail later.

Referring to Fig. 1, one may note that variables for a given luminaire, mounting height, and roadway width, may be represented by a family of curves showing the relationship between initial lamp lumens, luminaire spacing, average illumination, minimum and maximum horizontal footcandles on the pavement, and ratio of maximum to minimum horizontal footcandles on the pavement. The original data were secured from the iso-candle data by setting up the iso-lux curves, as shown in Fig. 15, for the particular conditions noted and then determining the various quantities shown.

Fig. 1 shows the performance curves for luminaire 1 based on the ASA recommended design procedure, which establishes a spacing based on an *average* footcandle value. It will be noted that for

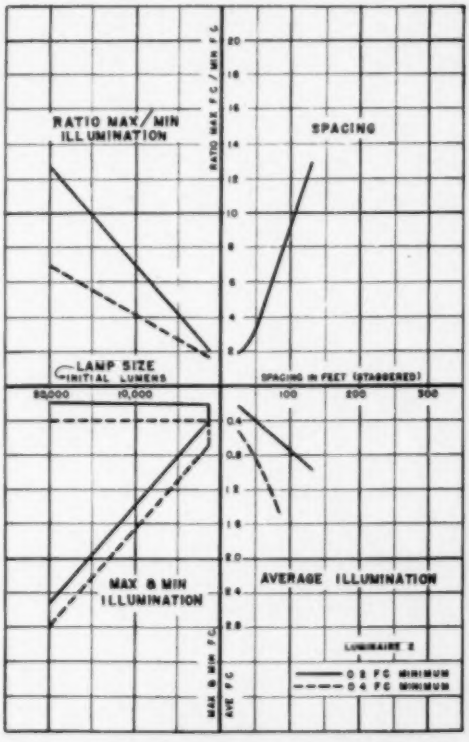


Figure 6. Luminaire performance curves. Mounting height 30 feet. Roadway width 70 feet. A.S.A. Type III (shielded). Minimum illumination method.

an average value of 0.6 ft-c the minimum and maximum illumination will vary from 0.49 to 0.66 ft-c for a 2,000-lumen lamp, and from 0.24 to 1.25 ft-c for a 20,000-lumen lamp. For the same lamp sizes, the spacings will vary from 15 to 140 ft and the maximum to minimum ratio of illumination will vary from 1.3 to 6.0.

A similar analysis of luminaire 2, based on ASA recommended design procedure, is shown in Fig. 2 and indicates that for an 0.60-ft-c average value the range of maximum to minimum illumination will vary from 0.50 to 0.75 ft-c for a 2,000-lumen lamp and from 0.00 to 2.5 ft-c for a 20,000-lumen lamp. The maximum to minimum ratio will vary from 1.5 to infinity, while the spacing will vary from 10 to 149 ft for these lamp sizes.

The A.S.A. recommended minimum illumination, which is one-quarter of the average value, is also shown on the curves of Figs. 1 and 2. It is evident from an inspection of Fig. 1 that at no time would the illumination from luminaire 1 fall below the minimum recommended value for a design based upon an 0.60-ft-c average, while in Fig. 2, using luminaire 2 and any lamp size in excess of 8,000 lumens, the minimum illumination would fall below that recommended by the A.S.A. It is evident from these two figures that although the average illumination was held constant in conformance to the Standard Practice, the illumination from the two types of luminaires varied over an extremely wide range. Unless the design engineer was thoroughly familiar with the character of each luminaire, the average footcandle determination would be meaningless in predicting the quality of the lighting job that would be obtained from the installation of the lights.

Because Standard Practice points out that good visibility at night can be obtained only by adequate pavement brightness with good uniformity, it is evident that some method should be used to specify a tolerance limit for uniformity of illumination in order that the lighting engineer will

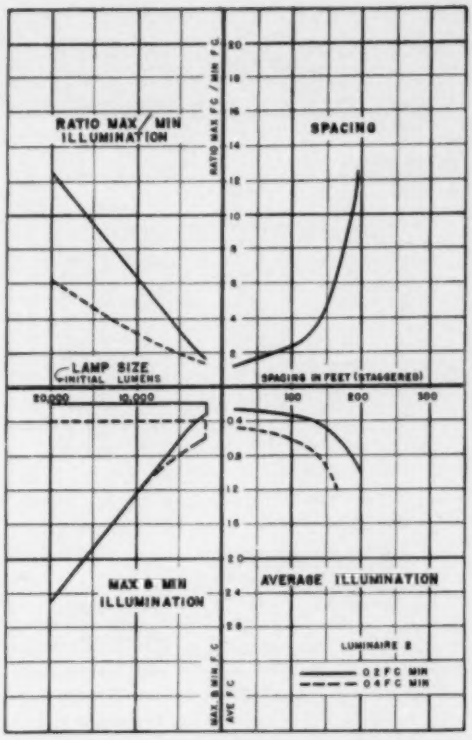


Figure 8. Luminaire performance curves. Mounting height 30 feet. Roadway width 28 feet. A.S.A. Type III (shielded). Minimum illumination method.

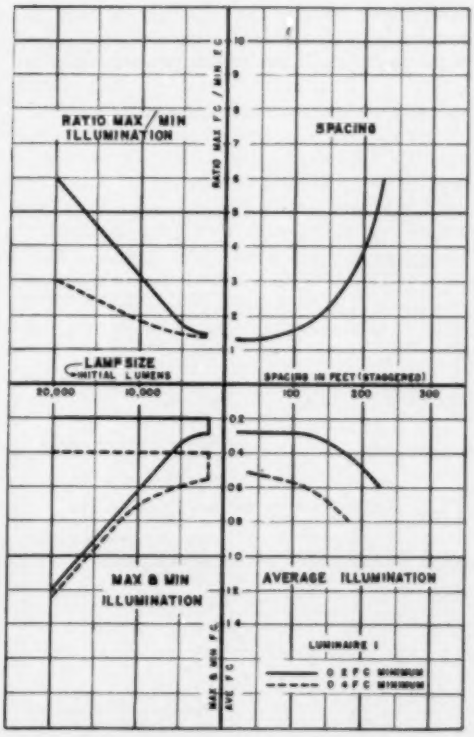
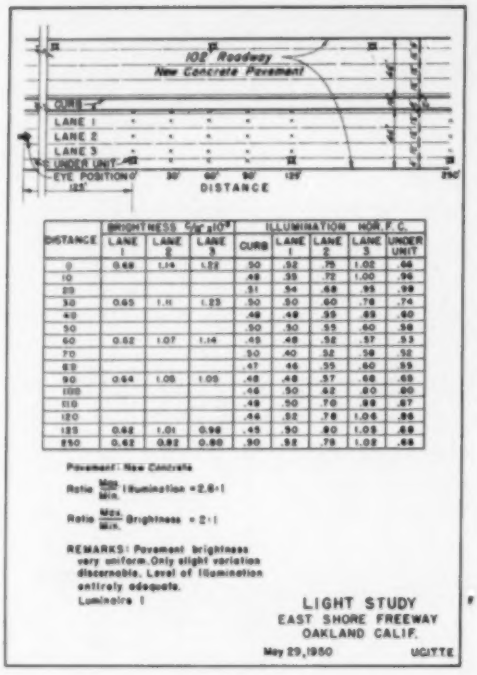


Figure 7. Luminaire performance curves. Mounting height 30 feet. Roadway width 28 feet. A.S.A. Type IV. Minimum illumination method.



DISTANCE	BRIGHTNESS L/π x10⁻⁴ LANE 1	LANE 2	LANE 3	ILLUMINATION HOR F.C. CURB	LANE 1	LANE 2	LANE 3	UNDER UNIT
0	0.68	1.14	1.22	.50	.52	.75	1.02	.66
10				.48	.55	.72	1.00	.96
20				.51	.54	.68	.95	.99
30	0.65	1.11	1.23	.50	.50	.60	.78	.74
40				.48	.48	.55	.69	.60
50				.50	.50	.55	.60	.56
60	0.62	1.07	1.14	.45	.48	.52	.57	.53
70				.50	.40	.52	.58	.52
80				.47	.46	.55	.60	.59
90	0.64	1.05	1.05	.48	.48	.57	.66	.68
100				.46	.50	.62	.80	.90
110				.48	.50	.70	.98	.87
120				.46	.52	.78	1.06	.96
125	0.62	1.01	0.98	.45	.50	.80	1.05	.88
250	0.62	0.82	0.80	.50	.52	.78	1.02	.66

Pavement: New Concrete

Ratio $\frac{\text{Max.}}{\text{Min.}}$ Illumination = 2.6:1

Ratio $\frac{\text{Max.}}{\text{Min.}}$ Brightness = 2:1

REMARKS: Pavement brightness very uniform. Only slight variation discernable. Level of illumination entirely adequate.
Luminaire 1

LIGHT STUDY
EAST SHORE FREEWAY
OAKLAND CALIF.
May 29, 1950 UGI.YTE

Figure 9.

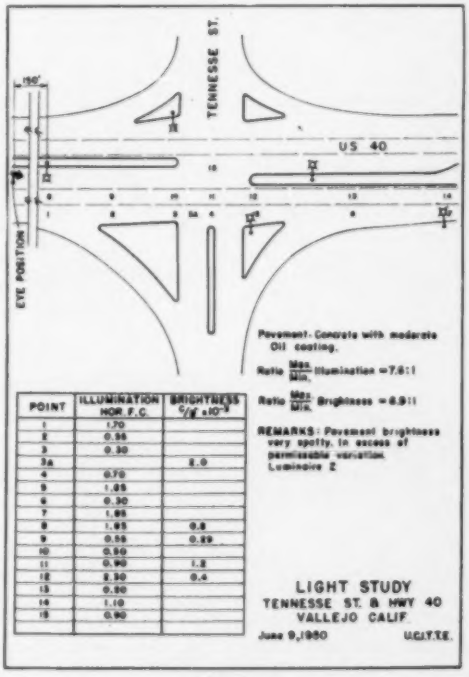
have a recommended range within which to work.

Figs. 1 and 2 also show that the *average illumination* method of making roadway lighting calculations does not yield information on uniformity. In the previous examples the luminaires develop illumination ratios as low as 1.5:1 in one case, and as high as infinity in the second case, even though the average illumination remained at 0.60 ft-c. Even if the designer remained entirely within recommended practice and limited the minimum illumination to one-fourth of the average, the illumination ratio could still be 17:1 for luminaire 2. Thus the recommended practice would appear to be incomplete if the idea of substantial uniformity is to be included.

It is recognized that the desirable quantity to be controlled and held substantially constant is the *pavement brightness* along each traffic lane as seen by the motorist. This end result is always sought by controlling the illumination. But the brightness is also a function of the directional angles of the light source and the observer and is dependent upon the pavement reflection characteristics. Thus the appearance of the roadway will be greatly affected by the mounting height and spacing of luminaires even though the *average* illumination is held constant for a series of different design layouts.

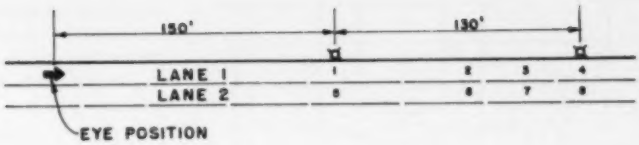
We are limiting this discussion to a consideration of conventional present practice in which roadway illumination is obtained from individual sources mounted overhead on poles. Future developments of line or other types of sources may lead to changes in the arrangement of equipment but should not require changes in the basic idea of designing for uniform pavement brightness along each traffic lane. It may be noted that there could be a permissible brightness gradient across a roadway depending upon the transverse location of the sources, but this is not considered to be as important as the variation in brightness *along* the roadway, which causes a "roller coaster" effect and reduces visibility by introducing a camouflage pattern in the surrounds.

The roadway surface characteristics will vary greatly with type of roadway and road use and are not usually under the control of the lighting designer. However, all of the other factors remain substantially constant once the lighting units are installed so it is important to know what to expect in the way of brightness variations for different in-



POINT	ILLUMINATION HOR F.C.	BRIGHTNESS L/π x10⁻⁴
1	1.70	
2	0.56	
3	0.30	
3a		2.0
4	0.70	
5	1.85	
6	0.30	
7	1.85	
8	1.85	0.8
9	0.56	0.29
10	0.50	
11	0.90	1.2
12	2.30	0.4
13	0.80	
14	1.10	
15	0.90	

Figure 10.



POINT	ILLUMINATION HOR. F.C.	BRIGHTNESS $C/B \times 10^{-3}$
1	.54	.49
2	.47	.75
3	.49	
4	.51	.39
5	.65	.30
6	.53	.37
7	.53	
8	.64	.25

Pavement: New Black Asphalt

Ratio $\frac{\text{Max.}}{\text{Min.}}$ Illumination = 1.2 : 1

Ratio $\frac{\text{Max.}}{\text{Min.}}$ Brightness = 3 : 1

REMARKS: Pavement brightness spotty. Considered maximum permissable variation. Luminaire 1

Figure 11

LIGHT STUDY
EAST SHORE FREEWAY
OAKLAND CALIF.
June 5, 1950 U.C.I.T.E.

stallations yielding known variations in horizontal illumination.

It has been observed by the authors and others[10] that the pavement brightness is *not* necessarily related *directly* to horizontal illumination, although the usual mathematical relationships show that brightness is directly proportional to illumination. This effect occurs because roadway surfaces are not diffuse reflectors, and because the important viewing angles are nearly 90° to the normal. For some nearly diffuse surfaces such as new broomed-concrete the brightness ratio has been observed to be much less than the illumination ratio, and the maximum brightness is in the area of maximum illumination. See Fig. 9. For a worn concrete roadway with moderate oil staining, the brightness ratio was observed to be slightly less than the illumination ratio, but the area of highest brightness was shifted from the region of maximum illumination toward the observer. For a typical asphalt roadway the brightness ratio was about 2½ times the illumination ratio, but the area of maximum brightness was shifted toward the observer and corresponded to the region of minimum illumina-

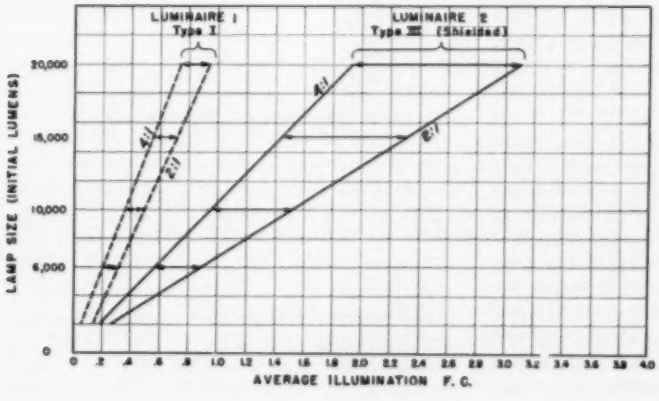


Figure 12. Range of illumination levels for various lamp sizes. Roadway 102 feet. Mounting height 30 feet. Uniformity ratio 2:1 to 4:1.

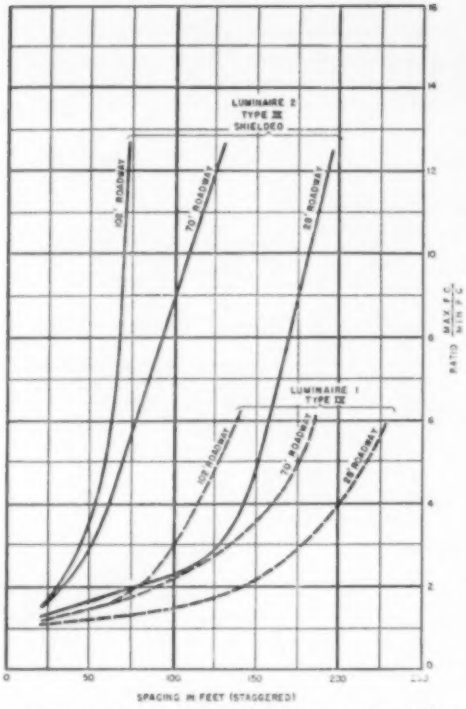


Figure 13. Spacing vs. illumination ratio for various roadway widths.

tion. It may be noted that it would be possible for the brightness ratio greatly to exceed the illumination ratio, but this is not generally the case. It would be if the road surface became very specular, as happens when wet.

The data that we have collected and shown in part in Fig. 9, as well as the researches of others[1] show that reasonable uniformity can be obtained for most pavement surfaces and mounting heights of 25 ft or more if the illumination ratio is within 4 to 1. The data shown in Fig. 10 will bear out this statement.

In order to incorporate the idea of illumination uniformity and that of adequate pavement brightness it would seem better to design to a *minimum* rather than an *average* value of illumination and, further, to adhere to a recommended maximum ratio of illumination. This procedure has been followed in Figs. 3 and 4. In these figures the A.S.A. values have been used as a guide to select the minimum illumination in the street area, and the luminaires have been so spaced that with a variation of lamp size the minimum illumination at any point on the roadway would be held constant.

Again comparing luminaires 1 and 2 on the basis of maintaining a constant *minimum* illumination reference is made to Figs. 3 and 4. For luminaire 1 using a 30-ft mounting height, a 102-ft wide roadway and a minimum of 0.2 ft-c illumination, the ratio of maximum to minimum illumination varies from 1.2:1 to 6:1 and the *average* illumination varies from 0.25 to 0.6 ft-c when the spacing is changed from 10 to 140 ft. For luminaire 2 installed under similar conditions the maximum to minimum illumination ratio varies from 1.5:1 to 13:1 and the average illumination varies from 0.25 to 1.2 ft-c when the spacing is changed from 10 to 70 ft. Obviously the spacings closer than about 50 ft are not of practical significance, but they do show the relationships among the variables.

It will be noted from Fig. 3 that luminaire 1 equipped with a 10,000-lumen lamp and installed to maintain a minimum illumination on the roadway of 0.4 ft-c would require a staggered spacing of 62.5 ft, which would result in an average illumination of 0.55 ft-c with a ratio of maximum to minimum illumination of 1.8:1.

In Fig. 4, using luminaire 2 equipped with a 10,000-lumen lamp and arranged to maintain the same minimum illumination of 0.40 ft-c, the required staggered spacing would be 50 ft and would result in an average illumination of 1.0 ft-c, with a maximum to minimum illumination of 3.6:1.

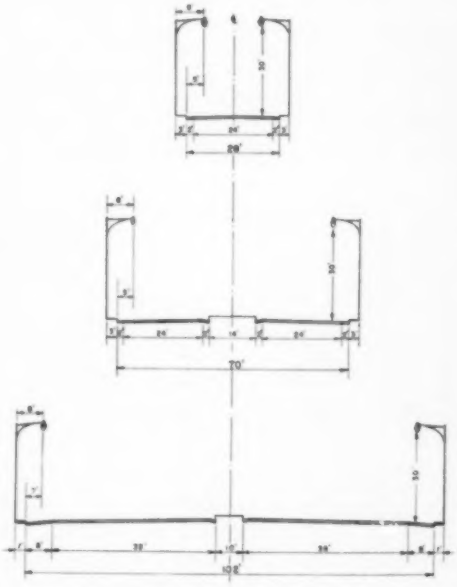


Figure 14. Detail of roadway sections.

If performance and economics are not to be disregarded, it is evident that luminaire 1 is superior, in that fewer units would be required and would provide a substantial improvement in the uniformity.

Of particular importance is the relation between uniformity of illumination, lamp size, and average illumination level. For an illumination ratio between 2:1 and 4:1 there is a definite correlation between lamp size and average illumination for luminaires 1 and 2. See Fig. 12.

The range of the average illumination that can be obtained from each lamp size for each luminaire can be determined. These values are tabulated in Table I for the luminaires studied.

TABLE I.—Range of Average Illumination for Illumination Ratios Between 2:1 to 4:1.

Roadway Width — 102 ft.
Mounting Height — 30 ft.

Lamp Size	Average Illumination for Ratio Between 2:1 to 4:1	
(lumens)	Luminaire 1	Luminaire 2
6,000	.15 - .35 h.f.c.	.50 - .90 h.f.c.
10,000	.30 - .55	.90 - 1.50
15,000	.50 - .75	1.40 - 2.30
20,000	.70 - 1.00	1.90 - 3.10

It is evident then that for each luminaire and the conditions assumed, there is a definite range of illumination levels to be obtained for each lamp size used, and the selection of the proper luminaire for a project should only be done after the complete performance characteristics are fully considered. Of the two luminaires studied it is evident that luminaire 1 would be best suited for illumination levels from .15 ft-c to .50 ft-c. Both Luminaires 1 and 2 would be suitable for light levels from .50 ft-c to 1.00 ft-c. Only Luminaire 2 would be suitable from 1.00 ft-c to 3.10 ft-c for the range of lamp sizes between 6000 and 20,000 lumens.

Or considering a fixed lamp size, a 10,000-lumen lamp would only be suitable for average illumination values between 0.30 ft-c to 0.55 ft-c when used in Luminaire 1, and between 0.90 ft-c to 1.50 ft-c when used in Luminaire 2. A 20,000-lumen lamp would only be suitable for average illuminations between 0.70 ft-c to 1.00 ft-c when used in Luminaire 1, and between 1.90 ft-c to 3.10 ft-c when used in Luminaire 2.

Similar analyses have been made on luminaires 1 and 2 for roadway widths of 70 ft and 28 ft and are shown in Figs. 3 to 8. An analysis of these curves will clearly indicate that the foregoing discussion of a 102-ft roadway applies equally as well to the studies for the 70-ft and 28-ft roadways. It

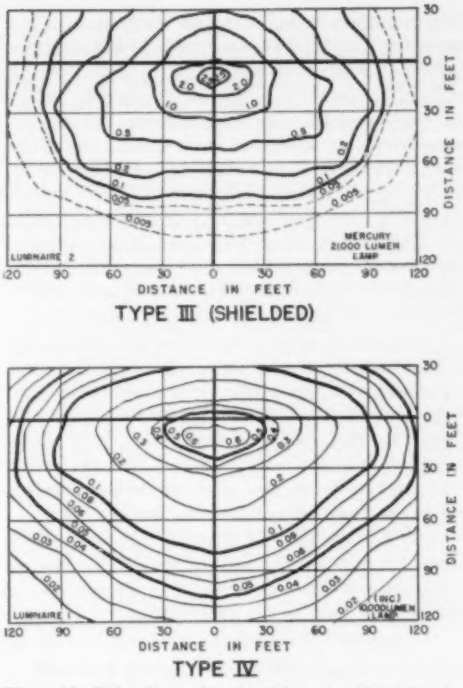


Figure 15. Isolux lines of horizontal footcandles. Mounting height 30 feet.

should be evident that a properly designed highway lighting system should include full consideration of all the physical factors involved in order that the luminaire and lamp size selected will provide the best visibility conditions for the level of illumination desired.

The effect of spacing on the illumination ratio is shown in the curves of Fig. 13 and further emphasizes the variation that exists between the performance of the two luminaires being studied. It may be noted that for each luminaire and mounting arrangement there is a maximum spacing that can be used for any given illumination ratio regardless of the lamp size.

Conclusions. — It has been the purpose of this paper to point out some of the inconsistencies that exist under the present A.S.A. Standard Practice for Highway Lighting Design and to suggest minor modifications that will permit a rational solution to the design problems based on sound engineering principles.

Because of the wide variations that do occur in luminaire performance, even among units having the same classification, and in view of the A.S.A.

recommendations that adequate visibility at night should be provided by designing for substantially uniform pavement brightness, it is logical that a ratio of maximum to minimum illumination should be established in order that highway lighting designs may have a common basis of comparison. In view of the general agreement as to the desirability of having substantially uniform pavement brightness, it is suggested that a value of 4:1 should be established as a recommended maximum variation in roadway illumination along extended sections of highway. This ratio could be used as a "figure of merit" in making appraisals of installations.

In order to provide a basic highway lighting design standard that will not be affected by luminaire characteristics, but will be determined by the lowest value of illumination that is considered adequate for the area to be illuminated, it is recommended that *minimum* values of illumination on the roadway be adopted as design criteria, instead of the average values now being used.

The average value of illumination should be retained to indicate the level of illumination desired and thus would determine the optimum size of lamp to be used in the final design.

A suggested modification of the Recommended Practice to incorporate these ideas is as follows:

TABLE II.—Recommended Illumination for Highway Lighting.

(May be substituted for Table VI in ASA Recommended Practice.)

Highways	0.15 f.c. minimum
Intersections & Conflict Areas	0.20 f.c. minimum
Maximum to minimum illumination ratio shall not exceed 4:1	
(a) The average values of illumination on the paved roadway shall not be less than twice the above values.	
(b), (c), (d) Same as corresponding paragraphs in Table VI, ASA Recommended Practice.	

TABLE III.—Suggested Illumination Ratios.

(For Minimum h.f.c. between 0.1 f.c. and 2.0 f.c.)

Ratio	Recommended Value	
Max/Min f.c.	Concrete Surface	Asphalt Surface
1½:1		Ideal Limit
2:1	Ideal Limit	Desirable Limit
3:1	Desirable Limit	Recommended Max. Limit
4:1	Recommended Max. Limit	

A summary of the Highway Lighting Design procedure suggested in the paper is as follows:

1. The minimum illumination for the roadway should be selected. See Table II.

2. The maximum to minimum ratio of roadway illumination should be selected. See Table III.

3. From luminaire performance data such as that presented in Figures 3 and 4 and Tables II and III obtain:
   a. Spacing
   b. Size of lamps
   c. Average illumination
   d. Maximum illumination
   e. Minimum illumination
   f. Ratio of maximum to minimum illumination
   g. Range of average illumination

With these data tabulated for each of the luminaires under consideration, a relatively simple economic analysis will enable the design engineer to select a proper unit. Thus in a short time a lighting project may be designed and all luminaires compared on a common basis with an accurate knowledge of the results to be expected.

Of course, when the larger lamp sizes are used and when different types of luminaires are being compared, an additional evaluation should be made of the glare conditions.

The addition of these suggestions to the present A.S.A. Standard Practice should provide criteria to help to establish uniformity in highway lighting design.

References

1. *American Standard Practice for Street and Highway Lighting*, Sept. 30, 1947, American Standards Assn., sponsored by I.E.S.

2. Reid and Channon: *Visibility on Lighted Streets*, G. E. Co. Bulletin LD-11 (February, 1940).

3. Reid, Kirk M., and Channon, H. J.: *Studies in Fundamentals of Highway Lighting*, Transactions of I.E.S., Vol. XXXI, p. 119 (February, 1936).

"Authorities, in general, appear to agree that the optimum light distribution for street and highway illuminations is one which provides substantially uniformity of pavement brightness."

4. *Code of Highway Lighting*, Transactions of the I.E.S., Vol. XXXII, pp. 143-147 (February, 1937).

"All illuminating engineers are agreed that a large portion of the light which is produced should be delivered upon the highway, and that this should be accomplished with the most uniform practical distribution of brightness and with the least practical glare."

5. *Traffic Safety Lighting*, Report by Sub-Committee on Recommended Practice of Street and Highway Lighting, Transactions I.E.S., Vol. XXXIV, p. 1047 (November, 1939).

6. Reid, Kirk M., and Channon, H. J.: *Evaluation of Street Lighting*, Transactions I.E.S., Vol. XXXIV, p. 1210 (December, 1939).

"Pavement brightness of adequate amount and fair uniformity with proportionate illumination of adjacent areas and with a reasonable minimum of glare from the luminaire, is needed for safe and comfortable driving at night on urban streets and on main rural highways."

7. *Recommended Practice of Street Lighting*, I.E.S. Committee on Street Lighting (1940).

8. *Recommended Practice of Street and Highway Lighting*, I.E.S. Committee on Street and Highway Lighting (1945).

"Good visibility at night may be attained by adequate pavement brightness with good uniformity and appropriate illumination of adjacent areas, together with reasonable freedom from glare."

9. Williams, Stuart R.: *Recommendation of Planning Modern Street Lighting*, Transactions of I.E.S., Vol. XLI, No. 2 (February, 1946).

10. Comments of Mr. T. W. Rolph, Transactions I.E.S., Vol. XXXI, p. 149 (February, 1936).

"...ratio of maximum to minimum illumination obtained in their (Reid & Channon) installation is stated to be 3 to 1. This is generally considered substantially uniform illumination in street lighting."

11. Sweet, Arthur J.: *Fundamentals of Rural Highway Lighting*, Transactions I.E.S., Vol. XXXI, p. 499 (May, 1936).

"... will produce a variation in brightness of 4 to 1. This is an acceptable approximation to uniformity."

DISCUSSION

KIRK M. REID*: This comprehensive study of uniformity of horizontal illumination sets a pattern for studies which may well be made of other factors in street lighting technology and practice.

The authors point out that some installations meeting the uniformity requirements of the American Standard Practice of Street and Highway Lighting have undesirably high variations in pavement brightness. This criticism serves as a reminder of one important use to be made promptly of the measurements of pavement reflectance characteristics in progress at the University of Illinois. From these data it is expected that patterns of pavement brightness can be charted for representative pavements with a variety of lighting systems meeting American Standard Practice. The permissible ratio of 4 between average and minimum horizontal illumination may be found too high for arterial streets, at least under some conditions.

The authors urge that minimum illumination be included as an important item in street lighting specification. To the extent that such a specification would discourage unduly wide spacings of luminaires it would be helpful. But it would also tempt luminaire designers to seek a competitive advantage by directing more light at relatively high angles. Such luminaires would give fairly good uniformity of horizontal illumination, even at relatively wide spacings — but with a penalty of increased glare. The authors make it clear that they are not asking for new luminaires with light distributions differing from those now available. Yet the British experience with a specification of minimum midpoint illumination was far from satisfactory. New luminaires did appear, with excellent ratings in terms of midpoint illumination but with serious glare losses both in visibility and comfort. Now that American street lighting installations are widely attaining levels adequate for safe seeing, all factors which contribute to more comfortable lighting warrant greater attention.

F. D. WYATT**: The article is extremely interesting and includes a new approach to the practice of street lighting. It is certainly a desirable thing, in any field of engineering, to be able to give a quick and thorough evaluation of a proposed installation. All methods of evaluation and all standards to be met must be kept within the financial means of those who are to use them. It is agreed that good visibility at night is best obtained by adequate pavement brightness, little glare, and good uniformity. As any civic system used by our society is a balance of economics, quality, and aesthetic values, so is the selection of the highway lighting design guided. The authors have dealt only with the quality of the system and have lost touch with the ever necessary balance.

The proposed illumination ratio of maximum to minimum of 4 to 1 is only possible by decreasing the spacing of the standards. As the author points out, a change of lamp size does not vary the max./min. ratio but only raises or lowers the average illumination level obtained from a given installation. Therefore, the proposed ratio would mean a tremendous increase in the number of standards needed. The installation cost for each mile of highway lighting would rise above the funds available for such work. The installations being made today are of high illumination levels. These installations have not only the aesthetic value, but also a suitable quality that can be justified by economics.

An article of this nature must be examined in complete detail to understand the reasoning behind the proposed changes. The authors have stated that the isolux diagrams were laid out as shown in Figure 15 and that the original data were secured from these curves. The authors chose a particular mounting height, street width, and luminaire type. They then plotted an isolux using the luminaire type and lumen lamp. These details are fully explained in the article. The remainder of the procedure is not so obvious and certain assumptions are necessary; the assumptions are based upon data given and fundamental concepts of illumination. It appears that the spacing was decided upon as the independent variable, and the lamp lumens required as the dependent variable. The spacing must have been decided upon first as there is only one value shown for both 0.6 Ave. ft-c and 0.8 Ave. ft-c. With the lumens required for a given spacing, it is possible to vary the isolux diagram according to the ratio of the lumens used in plotting the original and those needed at the desired spacing. The complete isolux for the necessary number of standards must have then been plotted. From these complete isolux diagrams, the maximum and minimum values could be obtained by the authors' curves plotted. This would appear to be the procedure used for obtaining the first two graphs.

Upon the assumption that the procedure was as noted above, several interesting things appear. It is stated that the Standard Practice is used for the first two curves; therefore, the calculations must have been made from:

$$\text{Lamp Lumens} = \frac{\text{Luminaire Spacing} \times \text{Ave. ft-c} \times \text{width}}{\text{Coefficient of Utilization}}$$

(The Coefficient of Utilization is dependent only on the type of unit, width of area, and mounting height. All these were constants for the calculations of Figure 1.)

It is important that the coefficient be known in order to discuss the merits of the figures. Therefore, the authors' assertion that a 2,000-lumen lamp is sufficient for a spacing of 15 feet will be assumed as correct.

Lumens	2,000
Ave. ft-c	0.6
Spacing	15′
Street width	102′
Coeff. of Util.	.458

$$\text{Coeff. of Util.} = \frac{15 \times 0.6 \times 102}{2{,}000} = .058$$

Then, checking this against the authors' claim for 140′ spacing:

$$\text{Lumens Required} = \frac{140 \times 0.6 \times 102}{.458} = 18{,}680 \text{ lumens}$$

The authors claim that when using a type IV luminaire and following the Standard Practice, a 2,000- and 20,000-lumen lamp would require a variation of spacing of 15 to 140 feet respectively for a 0.6 ft-c average illumination. By using the above calculated Coeff. of Util., based on the authors' assertion, the value was found to be 18,680 lumens. This would seem to be within reasonable results for the system.

However, if the same examination is applied to the second figure, a vast discrepancy is noted. Here again, the mounting height is 30 feet and the road width 102 feet, luminaire type III was used.

*General Electric Co., Nela Park, Cleveland, Ohio.
**Chicago Park District, Chicago, Ill.

Ave. ft-c	0.6	
Width	102′	
Spacing	10′	—Authors' claim
Lumens	2,000	
Coeff. of Util.	.306	

$$\text{C. U.} = \frac{10 \times 0.6 \times 102}{2{,}000} = .306$$

Now for 149′ spacing as used by the authors.

$$\text{Lumens required} = \frac{149 \times 0.6 \times 102}{.306} = 29{,}800$$

Mr. Simmons and Mr. Finch claim that, in accordance with the Standard Practice, a type 2,000- and 20,000-lumen lamp would require a variation in spacing from 10 feet to 149 feet. However, previously they had noted that the spacing varied directly as the lamp lumens, other conditions being constant. This is in accordance with Standard Practice. This would give a variation in spacing from 10 to 100 feet for these particular lamp sizes. The authors do not explain how they arrived at the 10 and 149 feet. As is shown above, again based on the calculated coefficient of utilization, the requirement for a 149-foot spacing is a 29,800-lumen lamp. The authors have either stretched the recommendation of the Committee on Street and Highway Lighting or the assumed calculations are in error.

Another aspect of the curve for a type III luminaire that is extremely doubtful and not thoroughly explained is the small change in spacing giving such a large change of the ratio. As indicated by the authors, a change of 71 feet to 75 feet causes a change of max. to min. ratio from 10 to 20 respectively. For a change of spacing of only 4 feet, doubling the ratio is extremely severe.

Also, in considering the validity of smooth curves, one would be better satisfied if the number of spacing considered and the exact positions of the points calculated were shown.

The authors further imply that by following the code, a ratio of max. to min. for a type III luminaire reached a value of infinity. Even if the given data are considered to be correct this is not the case. For if a line is drawn straight up from the point of intersection of the I.E.S. recommended minimum and the plotted minimum illumination curve, the drawn line will intersect the ratio curve at about 6 to 1 which is not excessive. The 6 to 1 ratio is a value that would fall within the Standard Practice.

The authors have made certain recommendations based upon theoretical curves. They would propose a definite minimum illumination be set for the highway. The Committee on Street and Highway Lighting made such a recommendation by stipulating that at no point shall the illumination level be less than ¼ of the average. This value is very appropriate and very definite.

The authors further propose that a maximum to minimum ratio be set up. This particular phase could possibly be of merit, but the authors' value of 4 to 1 as a maximum limit is not feasible at present. The required close spacing of standards would increase the cost of illuminating a roadway to a value which a majority of civic governments would find hard to justify. The ratio of 4 to 1 cannot be justified by engineering or economic analysis. Although the isolux curves are very useful for their present purpose, the accuracy of the combination of two or more such curves is difficult to control. More control is needed in the installation where the exact spot of maximum intensity is difficult to predict. It would, therefore, be very difficult to predetermine an installation within a 4 to 1 ratio, and a 1½ to 1 predetermination would be very unlikely.

The graphs demonstrated here are only a few of those necessary for the proposed family of curves. Each roadway width would require a new curve. Each curve is for one particulnr mounting height and one luminaire. How many graphs would be necessary for a complete family?

The authors have brought to light a subject of interest and one that may lead to a definite new system, but the proposed system cannot be used in its present form. An engineer should always be looking for a new and better approach to a problem — an approach which will yield a practical solution.

C. H. Rex*: Our congratulations to Mr. Simmons and Professor Finch for these excellent studies of roadway illumination. Furtherance of this work and coordination with that of others may result in improved methods for the installation of roadway lighting.

It is particularly gratifying to have this attention devoted to roadway lighting by the California Division of Highways and the Institute of Transportation and Traffic Engineering of the University of California. Such interest will increase the comfort, convenience, and safety with which our streets and highways may be used at night. That is a mighty important and vital objective.

For the purpose of comfort and convenience, the public is investing 1,400 million dollars per year for street and highway construction. And that 1,400 million dollars is only a small percentage of the money that the people spend each year for automotive transportation.

We must extend the public enthusiasm, acceptance, and use of lighting on this same important basis of comfort and convenience. Night driving must be more pleasant with less fatigue and annoyance from the brightness of light sources in the field of view.

The subject of this paper, "Visibility Requirements and Quality of Highway Lighting," has had considerable attention. It has resulted in luminaire developments which improve the seeing efficiency of roadway lighting. Light from more efficient sources is distributed so that it is more effective in producing visibility, with greater comfort for the public.

It is appropriate also that there is increased attention being devoted to the application of these new luminaires so that maximum seeing benefit per dollar cost is obtained from each installation. This will further enhance public enthusiasm for lighting.

The I.E.S. Committee on Street and Highway Lighting should increase their endeavor to determine the pavement brightness and the ratio of maximum to minimum pavement brightness that is practical and necessary for satisfactory visibility on various types of roadways. Similar conclusions should be arrived at for the veiling and discomfort glare ratios which are tolerable under practical conditions of driver and pedestrian behavior.

Investigations which will aid the I.E.S. Committee on Street and Highway Lighting are under way. I have suggested that the Committee make an analysis, starting with classification of roadway widths, spacings, and pavement surfaces on which the light distributions from luminaires are to provide a practical maximum in seeing benefit per dollar cost.

Messrs. Simmons and Finch evidently have arrived at some conclusions regarding the brightness and illumination

*General Electric Company, West Lynn, Mass.

ratios which are appropriate for California highways. That is progress which will be welcomed and seriously considered by those responsible for the improvement of night driving conditions in other states. This experience and engineering analysis of resulting benefit will aid in development of an improved future Standard Practice for Street and Highway Lighting.

All available proof data should be submitted for an increase in uniformity of illumination wherein the lowest footcandle value at any point on the roadway is not less than one-fourth the highest footcandle value instead of one-fourth the average illumination, as now recommended in the Standard Practice.

To aid in the lighting of highways in accordance with the suggestions made by Messrs. Simmons and Finch, we will furnish all such data as may be required. Just as a matter of interest, we have forwarded to them data sheets as furnished for luminaires manufactured in 1918. For spacings of from 100 to 300 feet these charts gave: (1) the variations in minimum horizontal footcandles; (2) average horizontal footcandles; and (3) the ratio of minimum to maximum footcandles all along the centerline of a 40-foot roadway. The data were based on pendent luminaires 25-foot mounting height, four-foot overhang, and showed the variations with size of lamps which are now rated at 10,000, 6,000, 4,000, and 2,500 lumens.

For many years it has been standard procedure to furnish the isocandle data on luminaire performance mentioned by the authors as well as isolux curves.

Modern luminaires efficiently control and proportion the light distribution so that larger lamps may be used to provide visibility with quality for good seeing. As the authors point out, these luminaires should be installed with due consideration for economy and the known requirements in accomplishing the visibility with quality objectives.

High-Bay Lighting in Large Industrial Area

Twin units containing two 1000-watt filament lamps are alternated with similar units of two A-H1 400-watt mercury lamps in the Turbine Works, General Electric Co., Schenectady, N. Y. Mounting height is approximately 45 feet. The units are vented at the top to allow convection currents to travel upward, carrying part of the dust and dirt up through the hole, instead of depositing it on the reflector and lamps.

Illumination level is 50 footcandles and the power requirement is 5¼ watts per square foot. Photo courtesy of General Electric Co., Nela Park, Cleveland, Ohio.

Daylight in Classrooms—Multilateral Lighting

By R. L. BIESELE, JR.

IN MOST classrooms, daylight is the primary light source. School officials, their architects, and particularly their lighting engineers should therefore know the practical techniques which are available for producing beneficial visual environments in classrooms, using daylight as the primary source.

This paper presents information obtained in an extensive investigation of classroom daylighting with windows in more than one wall — the so-called "bilateral" or "multilateral" arrangements. It presents a continuation of the studies of daylighting methods for classrooms reported in a previous paper.[1] The studies have been conducted under the author's direction at Southern Methodist University for some three years, and have been sponsored jointly by the Detroit Steel Products Company and the Libbey-Owens-Ford Glass Company.

The most extensive use of the multilateral window arrangements has been made in California, although they are appearing today in many localities. The multilateral arrangements were originally an outgrowth of the educational program of the California schools, for which it has been felt that a classroom 32 feet square possessed many advantages over the more conventional rectangular classroom. The daylighting problem presented by this wide classroom has resulted in some interesting classroom designs produced by architects in the area as they have attacked the problem.

Several years ago, Professor Leland H. Brown reported on the results obtained with some of the earlier examples.[2] In the examples reported by Brown, and in the many additional buildings designed and built since that time, the architectural attack has been mainly in terms of window design and placement with fixed light controls. The evaluation until recently has been chiefly in terms of amount and distribution of illumination in the rooms.

It has been the purpose of the present investigation to evaluate some of the typical arrangements in terms of brightness as well, so as to determine how effectively the various designs meet both the quality and quantity requirements of the American Standard Practice for School Lighting, 1948.[3]

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: Professor and Head, Department of Electrical Engineering, Southern Methodist University, Dallas, Texas.

Preliminary Investigation

As a preliminary to the more standardized tests contemplated in the current program, the author and his associate, Mr. J. W. Griffith, made an extended field survey of the newer California schools during the summer of 1949. Some hundred or more schools were visited during this survey, and illumination tests were made on many of these.

Variation among the designs was quite wide. In general, however, almost all the multilateral designs observed can be classified as one or the other of two basic types.

Basic Type No. 1, Bilateral. — One of these types appeared often enough that it might almost be considered a California standard. The basic classroom for this type, Fig. 1, is a 32-foot square room with the main window in the north wall of the room extending from a 12-foot ceiling to the sill, and occupying the full length of the wall. A second window extending from the ceiling down to eight to nine feet from the floor occupies the full length of the upper portion of the south wall. The south window is usually provided with a fixed external louver, although interior venetian blinds or outside overhangs were found in some designs. In many designs, the south window was located above the roof of an outside hall, which was given a highly reflecting surface to increase light utilization. In some designs, sloping ceilings were employed, in part to increase the effective height of the main

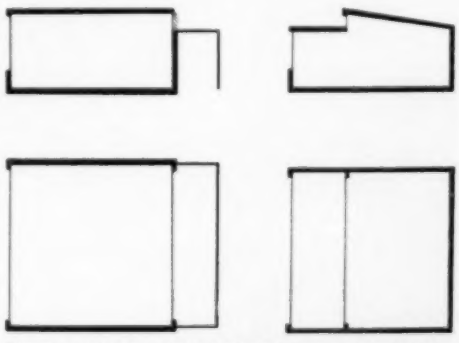


Figure 1 (Left). Typical bilateral classroom lighting design. Figure 2 (Right). Typical clerestory or monitor classroom lighting design.

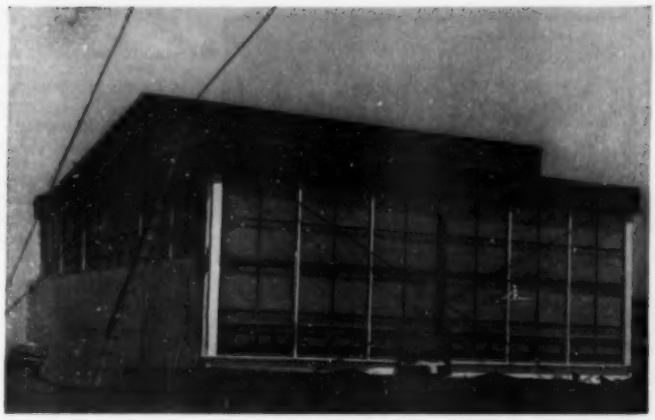


Figure 3. Daylight test building at Southern Methodist University, showing roof monitor with windows. Aluminum painted reflecting panels shown hinged down to side of building.

window without unduly increasing the volume of the room. The bilateral windows have been of material aid in natural ventilation for the rooms in the warmer climates.

Basic Type No. 2, Clerestory. — A second basic treatment, Fig. 2, is the use of a similar main window, also usually faced north, with a clerestory or monitor window set into the north side of a raised roof section to provide additional light for the inner portion of the room. Light reflecting surfaces are usually employed on the roof below the clerestory window, and in some designs a reflecting parapet is also employed. Sloping ceilings are common with this design, and in a few examples a third window is employed in the south wall similar to that for the bilateral design described in the preceding section.

As found, few of the buildings had an unobstructed sky, either because of trees, other buildings, or other portions of the same building. In some cases, exterior building areas and pavements acted as reflecting surfaces to improve the distribution of light in the classrooms. In other cases the exterior building surfaces visible through the windows were excessively bright and acted as glare sources when the windows were not equipped with controls such as interior venetian blinds. The decoration of the classrooms varied considerably, in choice of colors, although reflectances were in general within acceptable limits. Furniture arrangements varied, and in some cases children were apparently expected to face window areas directly, although most of the arrangements observed were reasonably good.

Test Program

Based on this preliminary survey, the program of standardized tests has been carried out as follows. Tests were run in the same building described in the previous paper. This building is 32 feet square, is oriented so that windows face the cardinal compass points, and has a clear view of the sky in each direction. Steel sash windows cover the full extent of each wall from 3½ to 14 feet above the floor. Additional windows were set into a monitor constructed on the roof, as shown in Fig. 3, to provide for the clerestory tests. The ceil-

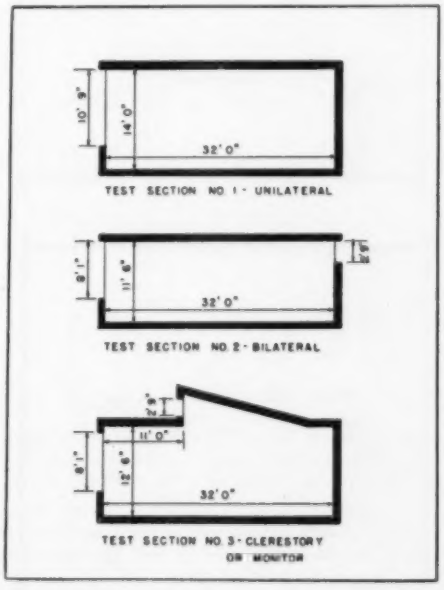
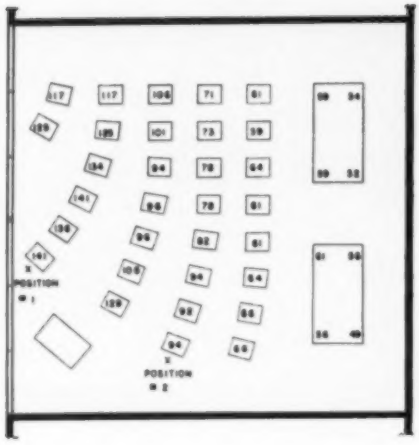
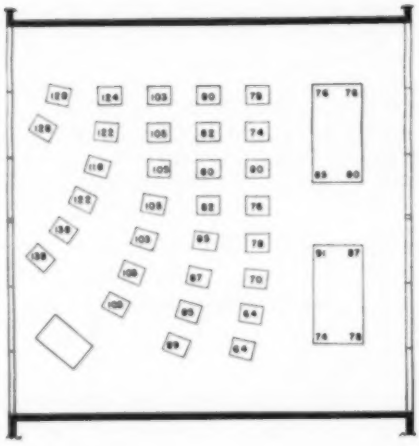


Figure 4. Sectional views showing window arrangements employed in the illumination and brightness studies reported in Tables I, II, and III of the paper.





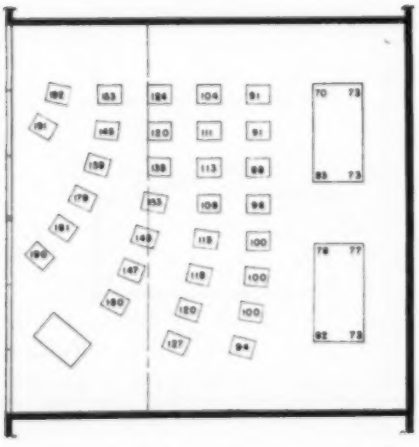


Figure 5 (Top). Illumination in footcandles, Test Section No. 1 — Unilateral. Test BL-4, with windows oriented north, clear north sky, clear glass, no controls at windows.

Figure 6 (Center). Illumination in footcandles, Test Section No. 2 — Bilateral, Test BL-17, with main windows oriented north, clear north and south sky, clear glass, no controls on north, horizontal louvers on south.

Figure 7 (Bottom). Illumination in footcandles, Test Section No. 3 — Clerestory or Monitor, Test BL-23, with windows oriented east, clear east sky, no sun on windows, clear glass, no controls at windows.

ing and walls are movable, to allow the room to be arranged in any orientation. Mock-up desks are employed, their tops tilted at 10 degrees.

Reflectances are the same as for the previous tests:

Ceiling	— flat white	— 85%
Walls	— greyed-green	— 60%
Floor	— natural finish pine	— 35%
Desks	— natural finish fir	— 40%
Task	— grey	— 70%

Room Designs Tested

The tests reported previously were for a 24 by 30-foot room with 12-foot ceiling, with window area representing approximately 34 per cent of the floor area. It was therefore decided that for comparative purposes, the basic tests in the current program should employ a 32 by 32-foot room with ceilings and window areas adjusted to give a window area of approximately the same percentage of the floor area in each case. Other window areas could, of course, have been employed, with changes in the quantity of illumination roughly proportional to the changes in the window area. The rooms reported here are as follows.

Test Section No. 1. Fig. 4.

Reference Test Arrangement. Room 32 feet square with 14-foot ceiling. Ten foot-nine inch windows in window wall, sill to ceiling, running length of wall.

Test Section No. 2. Fig. 4.

Bilateral Arrangement. Room 32 feet square, with 11′-6″ ceiling. Eight foot-one inch windows from sill to ceiling in main wall, running length of wall. Two foot-nine inch window in top of opposite wall, running length of wall.

Test Section No. 3. Fig. 4.

Clerestory Arrangement. Room 32 feet square, with broken ceiling as shown. Eight foot-one inch windows sill to ceiling in wall, running length of wall. To foot-nine inch window in roof monitor, running length of room, and facing same exposure as main window.

Orientation and Control Devices

Previous tests indicated that there are three basic daylight conditions which must be considered in the choice of room orientation and design of control devices, (a) overcast skies, (b) clear sky without sun, and (c) clear sky with sun on the windows.

In order to simplify the discussion, the tests reported here are based on either north or east exposures for the main window, with clear flat glass in all window areas. Windows are used (a) without control devices, (b) with horizontal louvers, (c) with reflectors extending outward horizontally below the auxiliary window, or (d) with both louvers and reflectors, as noted.

The horizontal louvers employed in the current tests were fabricated of wood frames with white enamelled metal slats of the type used in conventional venetian blinds. The blades are tilted at 45°, and are spaced to give complete cutoff below the horizontal.

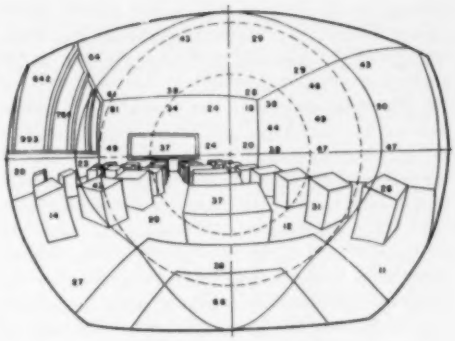
The reflector employed beneath the bilateral window consists of an 8-foot wide panel extending horizontally outward from the building immediately below the window. The upper surface of this panel is painted with a high quality aluminum paint which was employed to take advantage of its specular reflecting characteristic. This reflector corresponds to the roof of the outside hall common to the California schools. For the clerestory design, the reflecting surface consisted of white cloth on the original roof. Deterioration of these external reflecting surfaces will depend on the locality in which they are employed. As tested in this program, the surfaces were clean.

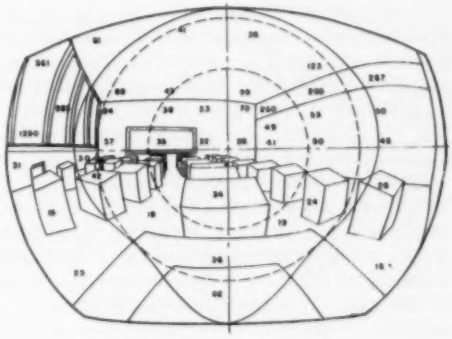
Seating Arrangement

For purposes of comparison, the seating arrangement employed was essentially identical to that employed for the tests previously reported, with the addition of tables in the right hand portion of the room which is used as an "activity" area in the California teaching program. This arrangement is shown in Figs. 5, 6, and 7 which show the illumination produced in each of the three classroom types studied, for equivalent sky conditions. Test positions (1) and (2) are identical with those employed previously, and Figs. 8, 9, and 10 show "heads up" brightness patterns for test position (2), corresponding to the conditions shown in Figs. 5, 6, and 7.

Test Method

The test procedure was briefly as follows:
(1) At the beginning and end of each test, readings were obtained of sky brightness along the





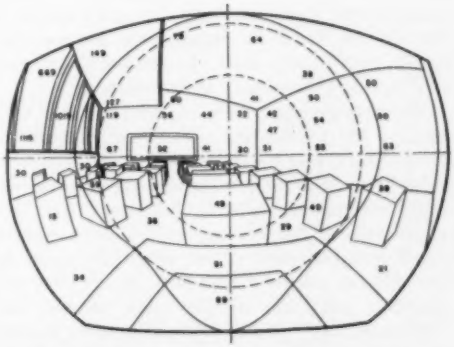


Figure 8 (Top). Brightness pattern for "heads up" view from Test Position No. 2, with unilateral window arrangement with clear sky and other conditions as for Fig. 5.

Figure 9 (Center). Brightness pattern for "heads up" view from Test Position No. 2, with bilateral window arrangement with clear sky and other conditions as for Fig. 6.

Figure 10 (Bottom). Brightness pattern for "heads up" view from Test Position No. 2, with clerestory or monitor windows with clear sky and other conditions as for Fig. 7.

horizon, at 45° altitude, and at the zenith. Readings of illumination incident on the outside vertical face of the windows were also obtained at beginning and end of the test.

(2) Readings were then obtained of the illumination on the desk tops, and of the brightnesses of the different room and furniture surfaces, and of the windows or light control devices which were visible from the two test positions shown on Fig. 7.

(3) All readings reported were made with the Luckiesh-Taylor Brightness Meter, whose calibration has been checked at intervals during the test program. Illumination readings were made with this instrument by measuring the brightness of movable test plates having a diffuse surface of known reflectance.

(4) To establish a quantitative base, a Weston color and cosine corrected barrier layer cell instrument was placed on a central desk in the room, and the reading of this instrument was noted for each brightness reading made with the Luckiesh-Taylor instrument. All readings for a test were then corrected to a common "inside base," and are reported here as the "as found" readings.

(5) In the Recommended Practice of Daylighting,[4] the standard sky is considered as a hemisphere having a uniform brightness of 1000 footlamberts, the approximate brightness of an average overcast sky. It is approximately the value (Recommended Practice of Daylighting,[4] Table I, after Kimball) for 9 a.m. and 3 p.m., March 21 and September 21 for 42° N. Latitude. Such a source would produce 1000 footcandles on an unobstructed exterior surface, and if no ground reflection were assumed, would produce 500 footcandles on an exterior vertical surface such as the windows.

The tests have therefore also been adjusted to a base of 500 footcandles incident on the exterior vertical surface of the main window, with no direct sunlight on this window, to correspond conservatively with this standard sky brightness. This is a quantitative adjustment only, which does not affect this brightness ratios. These values are shown in the columns headed "Standard Sky." For the condition with sun on the main window, the "Standard Sky" base is taken arbitrarily as 4000 footcandles incident on the vertical face of the main window.

For other conditions of sky brightness, or of sunlight on the windows, or for other locations or times, the values shown in the test results can be adjusted quantitatively. It is necessary only to multiply the readings by the ratio of assumed sky brightness to standard sky brightness, or the ratio of assumed incident illumination to standard incident illumination at the windows. Specific data on sky brightness is included in the Recommended Practice of Daylighting.[4]

Test Reports

The tests reported here are listed in Table I. Table II gives a condensed summary of the illumination results obtained for the various arrangements. Table III gives the brightness data for the various arrangements.

The data indicate that for all arrangements tested, except one, the illumination at every point in the room had a value greater than the 30 footcandles recommended in the American Standard Practice for School Lighting, when values were adjusted to a base of 500 footcandles incident on the main windows. The exception had a minimum value of 29. Only one set of readings had values below 30 footcandles as found, and that set was taken during one of the darkest overcasts of any duration encountered during the three-year test program.

As before, values of illumination diversity were quite low, and were in general somewhat better for Test Sections No. 2 and No. 3 than for the uni-

TABLE I.—Tests Reported.

Test No.	Conditions
BL-3	Test Section No. 1, overcast north sky, clear glass, no controls. Test made 2:17 to 3:00 p.m., Jan. 20, 1950.
BL-4	Test Section No. 1, clear north sky, clear glass, no controls. Test made 2:40 to 3:20 p.m., Feb. 2, 1950.
BL-17	Test Section No. 2, clear north and south sky, clear glass, no controls on north, horizontal louvers on south. Test made 2:40 to 3:28 p.m., March 29, 1950.
BL-18	Test Section No. 2, clear north and south sky, clear glass, no controls on north, horizontal louvers on south with reflectors under south windows. Test made 2:19 to 2:59 p.m., March 30, 1950.
BL-19	Test Section No. 2, overcast north and south sky, clear glass, no controls on north, horizontal louvers on south. Test made 10:33 to 11:00 a.m., March 31, 1950.
BL-20	Test Section No. 2, overcast north and south sky, clear glass, no controls on north or south. Test made 11:00 to 11:32 a.m., March 31, 1950.
BL-21	Test Section No. 2, overcast north and south sky, clear glass, no controls on north, reflector under south windows. Test made 9:30 to 10:00 a.m., April 12, 1950.
BL-22	Test Section No. 2, overcast north and south sky, clear glass, no controls on north, horizontal louvers on south, with reflector under south windows. Test made 2:00 to 2:40 p.m., April 12, 1950.
BL-23	Test Section No. 3, clear east sky, no sun on windows, clear glass, no controls. Test made 1:34 to 2:15 p.m., May 17, 1950.
BL-24	Test Section No. 3, clear east sky, sun on windows, clear glass, horizontal louvers on all windows. Test made 9:07 to 9:44 a.m., May 18, 1950.
BL-25	Test Section No. 3, overcast east sky, clear glass, no controls. Test made 12:38 to 1:07 p.m., May 20, 1950.
BL-26	Test Section No. 3, overcast east sky, clear glass, no controls except reflecting roof under clerestory windows. Test made 1:12 to 1:37 p.m., May 20, 1950.
BL-27	Test Section No. 3, clear east sky, sun on windows, clear glass, horizontal louvers on all windows, reflecting roof under clerestory windows. Test made 9:07 to 9:43 a.m., May 23, 1950.
BL-28	Test Section No. 3, clear east sky, no sun on windows, clear glass, no controls except reflecting roof under clerestory windows. Test made 1:44 to 2:18 p.m., May 23, 1950.

TABLE II.—Illumination Studies.

EL Test No.	Avg. Sky Brightness Footlamberts			Vert. Illum. on windows in Ft-c		Avg. Illum. on Desks in Ft-c		Avg. Illum. on Tables in Ft-c		Avg. Room Illum. @ Desk Ht. in Ft-c		Min. Desk Illum. in Ft-c		Min. Illum. on Tables in Ft-c		Illum. Diversity
	Hor. @ North	Hor. @ South	Zenith	North Wd.	South Wd.	As Found	Std. Sky	As Found	Std. Sky	As Found	Std. Sky	As Found	Std. Sky	As Found	Std. Sky	Max./ Min.
3	174	—	661	211	—	54	127	17	41	41	98	22	51	15	36	7.4
4	980	—	291	458	—	87	95	51	56	75	28	54	59	45	49	2.9
17	1313	2086	410	522	3307	101	97	84	80	95	91	67	64	77	74	2.2
18	1173	2008	522	570	3900	119	105	124	109	120	106	90	79	112	98	1.9
19	662	795	1708	938	1228	171	91	56	30	132	70	73	39	54	29	7.5
20	774	977	1773	793	819	205	129	128	80	186	112	123	77	125	79	3.2
21	740	496	1485	604	582	125	103	85	70	111	92	77	64	84	69	3.3
22	630	518	1029	536	543	95	88	43	40	77	72	47	44	39	37	6.0
23	1368*	—	1052	628*	—	163	130	95	76	140	112	111	88	88	70	2.7
24	3964*	—	2203	6153*	—	197	128	105	69	174	108	138	90	98	64	2.8
25	1425*	—	4547	1345*	—	373	139	165	61	303	113	200	74	155	58	5.4
26	1525*	—	5000	1530*	—	431	141	184	60	348	114	246	80	172	56	4.9
27	2987*	—	938	5904*	—	208	141	112	76	176	119	140	95	103	70	2.8
28	1422*	—	590	720*	—	200	139	111	77	170	118	137	95	102	71	2.9

*East.

TABLE III.—Brightness Studies.

Test	Head Position	0-30		0-50		0-90		Wd./Adj.
		Max./ Task	Task/ Min.	Max./ Task	Task/ Min.	Max./ Task	Task/ Min.	
3	1 up	3.0	3.3	3.2	3.3	26.6	3.3	17.6
	1 down	1.0	1.8	1.0	7.0	1.0	11.3	—
	2 up	1.3	3.4	2.1	3.5	29.8	3.4	19.7
	2 down	1.0	1.7	1.0	7.1	6.8	8.9	23
4	1 up	1.4	1.9	1.8	3.0	24.3	3.0	50.7
	1 down	1.0	1.8	1.0	6.6	1.0	7.6	—
	2 up	1.2	3.1	2.2	3.1	26.8	3.4	49.7
	2 down	1.0	1.7	1.0	6.0	16.2	6.0	53.8
17	1 up	8.7	1.2	9.1	1.6	25.5	1.6	32.8
	1 down	1.0	1.8	7.0	3.9	1.0	3.9	—
	2 up	7.4	1.9	7.4	1.9	35.7	2.2	40.3
	2 down	1.0	1.7	1.0	3.9	21.5	4.1	33.2
18	1 up	7.0	2.2	8.6	2.4	16.7	2.8	31.5
	1 down	1.0	1.8	1.0	5.7	1.0	5.7	—
	2 up	8.8	3.1	8.8	3.1	16.2	3.1	32.6
	2 down	1.0	1.8	1.0	3.9	16.9	3.9	30.8
19	1 up	3.3	1.6	3.7	1.2	30.8	1.2	14.5
	1 down	1.0	1.8	1.0	6.3	1.0	7.5	—
	2 up	3.9	2.9	3.9	2.9	23.9	2.9	21.2
	2 down	1.0	1.7	1.0	4.2	12.1	4.2	24.0
20	1 up	24.8	1.7	24.8	1.7	24.8	1.7	40.5
	1 down	1.0	1.7	1.0	4.0	1.0	4.6	—
	2 up	21.0	2.8	21.0	2.8	23.1	3.0	34.2
	2 down	1.0	1.7	1.0	4.5	10.2	4.5	22.4
21	1 up	21.9	1.8	24.1	1.8	24.1	1.8	31.1
	1 down	1.0	1.7	1.0	5.3	1.0	5.6	—
	2 up	27.3	2.8	27.3	2.8	27.3	2.8	48.0
	2 down	1.0	1.8	1.0	3.9	9.7	3.9	17.7
22	1 up	2.9	2.2	3.5	2.2	33.3	2.2	20.9
	1 down	1.0	1.7	1.0	4.5	1.0	5.8	—
	2 up	1.5	3.8	1.8	3.8	24.1	3.8	27.7
	2 down	1.0	1.8	1.0	5.4	12.3	5.4	26.4
23	1 up	1.3	1.9	2.0	1.9	17.9	1.9	31.8
	1 down	1.0	1.8	1.0	3.9	1.0	4.7	—
	2 up	1.1	1.7	2.3	1.8	21.4	3.5	37.1
	2 down	1.0	1.8	1.0	4.2	12.3	5.9	46.0
24	1 up	1.5	1.9	3.6	1.9	8.0	1.9	10.0
	1 down	1.0	1.8	1.0	3.2	1.0	3.5	—
	2 up	1.1	2.0	6.7	2.0	9.2	3.5	12.6
	2 down	1.0	1.7	1.0	3.9	5.2	6.2	12.6
25	1 up	2.7	2.8	3.0	2.8	23.0	2.8	15.7
	1 down	1.0	1.8	1.0	5.4	1.0	6.1	—
	2 up	1.0	2.5	2.4	2.5	20.5	4.2	16.6
	2 down	1.0	1.7	1.0	2.9	6.5	6.6	15.5
26	1 up	2.7	2.4	2.8	2.4	22.6	2.4	21.6
	1 down	1.0	1.8	1.0	4.9	1.0	7.7	—
	2 up	1.0	2.4	3.0	2.4	22.3	4.1	17.6
	2 down	1.0	1.8	1.0	3.7	6.4	7.1	46.8
27	1 up	1.3	2.0	3.5	2.0	5.9	2.0	7.7
	1 down	1.0	1.8	1.0	3.3	1.0	3.3	—
	2 up	1.1	1.9	9.0	1.9	10.6	2.5	12.7
	2 down	1.0	1.8	1.0	3.6	5.5	4.1	10.8
28	1 up	1.4	2.0	3.6	2.0	14.6	2.0	23.8
	1 down	1.0	1.7	1.0	4.7	1.0	4.7	—
	2 up	1.1	2.0	5.3	2.0	16.4	2.6	24.4
	2 down	1.0	1.8	1.0	3.9	12.0	4.1	25.8

lateral design of Test Section No. 1. As found previously, greatest diversities were found with overcast skies, because of their relatively high zenith brightness. Since both illumination and brightness recommendations have been in the main either met or exceeded, it is felt that this diversity is of little consequence.

It is of interest to note that the illumination values for the 32-foot square room with 14-foot ceiling and unilateral windows, correspond very closely with those obtained for the 24 x 30 foot room with 12-foot ceiling of the tests reported in the previous paper. It is also of interest that the average illumination, based on standard sky conditions, is in the neighborhood of 100 footcandles for each of the tests reported, with daylight alone as the source of light.

Brightness Data

The brightness ratios shown within the 0°-30°, and 0°-50° zones almost all fall within or very near the one to one-third and one to one-tenth ratios recommended in the American Standard Practice for School Lighting,[3] except the bilateral arrangement of Test Section No. 2, where the auxiliary window introduced an area of high brightness

The Bilateral Section No. 2 presents a difficult seating problem. By examination of the test data, however, it appears that a lower reflection factor on the under surfaces of the blinds on the south windows, of the order of 25 to 30 per cent of the present reflection factor, will reduce the brightness ratios to within the limits recommended in the American Standard Practice for School Lighting.[3]

A number of the ratios of brightness between window and adjacent wall area exceeded the 20 to 1 ratio recommended as tested. This situation is produced by bright, hazy skies, bright overcasts, or scattered sunlit clouds. These sky conditions were encountered repeatedly in the field survey in California, and have since been observed in such widely scattered locations as Dallas, Washington, D. C., New York City, Detroit, Toledo, and Chicago. It is reasonable to assume that they are apt to be encountered anywhere, although possibly not with the frequency encountered in California and the Southwest. Where such sky conditions are common, it may well be desirable to provide venetian blinds or some other suitable type of control on all extensive window areas. Since the designs tested provided considerably more than the minimum illumination recommended, such brightness controls could be introduced without reducing the illumination below recommended levels.

Examination of the brightness ratio data for the "heads down" positions indicates how close an approach to the ideal these test arrangements are producing. *In every case, for the "heads down" position, the visual task has been the brightest area in the 0-50 degree field.*

Conclusions

1. The daylighting problem is no more difficult for the 32-foot square classrooms than for the more conventional rectangular classroom.

2. With careful correlation of fenestration, light controls, decoration, and seating, designs meeting all the recommendations as to quality and quantity contained in the American Standard Practice for School Lighting can be readily attained.

3. With 14-foot ceiling height and 10-foot 9-inch windows, unilateral lighting can meet all requirements for the 32-foot wide room as well as for the 24-foot wide room with 12-foot ceiling reported in the previous paper.

4. Test Section No. 1, (unilateral), produces illumination levels and brightness ratios for the 32-foot wide room with 14-foot ceiling, which are almost identical with those produced in the 24-foot wide room with 12-foot ceiling.

5. Test Section No. 2, (bilateral), provides a more even distribution than a unilateral design by increasing the illumination near the auxiliary windows. It has the further advantage that sunlight can be permitted to enter from one elevation, if and when available and desired. This design presents a problem in seating arrangement, as indicated earlier, but affords the best arrangement for natural ventilation of the three.

6. Test Section No. 3 (clerestory or monitor) gives a very even light distribution and the most effective utilization of light quantitatively of the three sections.

7. Where sunlight is desired, or on orientations where sunlight is unavoidable, venetian blinds afford a satisfactory control method, by which sunlight can be excluded or admitted, as desired.

8. If under no conditions sun is to enter, and a minimum of controls is desired, Test Section No. 1 or No. 3 is indicated, oriented north. Section No. 2 could be employed, with main window oriented north, and south windows provided with fixed louvers.

9. Venetian blinds or other shielding devices at all windows may be desirable in geographical areas where high sky brightnesses are common.

10. Exterior reflecting surfaces will increase the admitted daylight, but tests indicate that adequate quantity is obtainable without them.

11. Increases or decreases in window area, caused by increases or decreases in ceiling height,

will change the amount of daylight in approximately the proportion that glass area is changed.

12. The 100-footcandle lighting system is entirely feasible, with daylight alone. However, as the higher illumination levels are attained, qualitative limits on brightness ratios must be maintained with increasing rigor.

Recommendations

Daylighting design is too complex to be condensed into a few sentences as a set of recommendations which will insure an effective daylighting system. Daylighting design requires and has had competent engineering study. The following set of simple recommendations is suggested as a starting point for good daylighting design. The recommendations are drawn from the experiences of the author in the extensive study proram described in this and earlier papers.

(a) Window areas should extend from wall to wall and as near the ceiling as possible. Mullions, muntin bars, or other structural details should be held to a minimum.
(b) Clear glass should be employed for the maximum admission of daylight and to permit clear vision to the out of doors.
(c) Venetian blinds provide effective control for direct sunlight, high sky brightness, or reflected glare from the outside, assist the distribution of light in the room, and permit natural ventilation.
(d) A seating arrangement should be employed which minimizes brightness ratios in the 0-50 degree field.
(e) Highly reflecting, non-glossy surface finishes within the limits recommended in the American Standard Practice for School Lighting should be used to increase illumination by inter-reflection and to afford proper control of brightness ratios.

If these simple recommendations are followed, classroom daylighting designs meeting all the requirements of the American Standard Practice for School Lighting are virtually assured. What is again perhaps most important, if such design for daylight is incorporated in the original architectural design of the building, it can be had at little, and possibly at no added cost.

References

1. Biesele, R. L., Jr.: "Daylight in Classrooms," ILLUMINATING ENGINEERING, Vol. XLV, p. 447 (July, 1950).
2. Brown, Leland H.: "The Design of Classrooms for High Level Daylight Illumination," ILLUMINATING ENGINEERING, Vol. XXXVI, p. 411 (March, 1941).
3. "American Standard Practice for School Lighting," A23—1948, ILLUMINATING ENGINEERING, Vol. XLIII, p. 793 (September, 1948).
4. "Recommended Practice of Daylighting," ILLUMINATING ENGINEERING, Vol. XLV, p. 107 (February, 1950).

DISCUSSION

H. B. VINCENT*: The importance of providing good lighting for schools and other areas where close-centered visual activities are undertaken is thought to be beyond question. The work sponsored by the Detroit Steel Products Co. and the Libbey-Owens-Ford Glass Co. provides a welcome addition to information on daylighting and the performance of accessories which may be used with the companies' products for control of brightness.

It is noted with approval that the author views unfavorably the subjection of students to light from the sky without some form of brightness control. Further, his test section #2 had not been developed to a point where he found its performance acceptable. Among the tests reported, this would appar to leave only two, BL-24 and BL-27, which were made on approved structures. Both are for sun exposure. It is hoped that work is in process looking toward reporting performance data for clear sky without sun and for overcast for both desks and tables.

In reviewing Figs. 8, 9, and 10, it appears uncertain why the line of sight is not directed toward the task. Advice of the author is sought as to whether Texans are addicted to this type of vision. For more normal vision centering on the designated task, brightness ratios in the 50 field would appear to run 20 to 25. Further from brightnesses shown in the diagram, it would seem that the reflectivity of the chalkboard must be in the neighborhood of 60 per cent, matching approximately the reflectivity of the wall. Does the author recommend so light a chalkboard? Conventional greenboards having reflectivity around 35 per cent would, of course, nearly double the ratio mentioned above.

For the "heads-down" position, the author makes a substantial point of the fact that the task is the brightest area in the 50 field. Since the task has the highest reflectivity in the area, is this not largely a matter of decoration rather than lighting?

The author is to be congratulated on the assembly of an interesting factual paper. It is hoped that he will give us more of them.

W. C. RANDALL**: Can the author assign some rough numerical value or suggest a method to define more precisely the meaning of the sentence on page 216, "The tests have therefore been adjusted to a base of 500 footcandles incident on the exterior vertical surface of the main window with no direct sunlight on this window to correspond conservatively with this standard sky brightness." It is important that investigators in the daylighting field should use similar methods to evaluate and compare results.

For a uniform sky the footcandles incident on the window are one-half the footlambert brightness of the sky. What is the relationship for a non-uniform sky — that is the question. In the absence of a well-defined method insofar as my knowledge is concerned, I have used mathematical computations and come up with adjusted figures for the footcandles on the window considerably less than shown. I am of the opinion that the differences can be explained by the effect of ground reflectances. Conservatively the increments due to ground reflectances can be in the range of from 0 per cent to 50 per cent, for the test conditions, the higher figure being for clear skies. Would the author check my general conclusion that the footcandles shown on page 214 are probably conservative or low in the magnitude of an average of say 20 to 25 per cent.

Would Mr. Biesele care to comment as to whether or not there is some foundation in the thinking of certain people that the brightness of large openings, such as windows, should be controlled or subject to control to a brightness of, say, 500 footlamberts, compared with a similar line of thought that luminaires should be controlled to a brightness of, say, 1000 footlamberts.

*Owens-Illinois Glass Co., Toledo, Ohio.

**Detroit Steel Products, Detroit, Mich.

R. W. McKinley*: I would like to confirm Professor Biesele's observation regarding California leadership in bilateral lighting. I have visited classrooms in all parts of the country in which fenestration has been included in more than one wall. However, in California bilateral daylighting seems to be the rule.

Prior to the Pasadena conference, I spent several days visiting "California-Style" schools. I saw several interesting methods for daylight control. In some of these California schools, where both light-directing glass blocks and shaded flat glass were used to solve brightness control problems, it was of especial interest to find that the glass blocks were given the more difficult task of sun brightness control and that the clear glass and venetian blinds were used on an elevation protected from exposure to direct sunlight.

At Orange Coast Junior College in Costa Mesa, we made careful surveys of the performance of a fenestration plan in which glass blocks were used in the south elevation clerestory. Clear glazing partially shaded by a roof projection was used in the north wall. It is interesting to compare our results (see illustration in "A simple Daylighting Survey Technique," page 172) with those reported by Professor Biesele for flat glass. The uncomfortably high brightness of the sky viewed through the clear glass is immediately noticeable.

Foster K. Sampson*: Professor Biesele and his associates are to be congratulated for compiling the information for this paper. Certainly the accuracy is satisfactory to determine major trends; however, there are several points I would appreciate having clarified.

First, Table III is based upon untold volumes of data which are not published; however, I become confused in attempting to check back against diagrams in Figures 8, 9 and 10. For example, from Table III, Test 20, Position 2, "Heads Up," shows 21 to be the maximum-to-task brightness ratio in the 0-30 degrees cone. In Figure 9, the maximum brightness in the 30 degree cone is shown as 260 footlamberts and the task is 62 footlamberts. On this basis the ratio is only 4.2. Even though the values shown in Figure 9 are not the ones used in compiling data for Table III the ratio should be at least similar. It is difficult to see how there could be such a wide difference. There are other similar discrepancies and for this reason I am asking why my interpretation of the published material is in error.

Secondly, in most of the elementary schools being built in California, the furniture is movable. All desks and tables are informally arranged in rooms used for kindergarten through the third grade. After the third grade more formal arrangements are found, but in many cases the classes are faced completely away from the window in order to avoid glare. Many people in the educational field are of the opinion that complete freedom of desk arrangement is essential for maximum efficiency of the educational process. Why do we then, as lighting engineers, try to force the arrangement of furniture into a set pattern which does not meet the educational requirements? At least in the conclusion of any study of classroom lighting we should acknowledge the desirability of more complete light conditioning in order to provide the ultimate in comfort and flexibility.

Thirdly, in point 9 of the conclusion Professor Biesele states that venetian blinds or other shielding devices *may* be desirable in areas where high sky brightness is common. It is our feeling that in order to do a complete job, a fixed shielding device is a necessity. Adjustable equipment is rarely in a proper position because teachers are too busy to keep it in proper condition.

*Pittsburgh Corning Corp., Pittsburgh, Pa.
*S. K. Sampson Co., Los Angeles, Calif.

Pure-Color Sources for Examining Proof

In the color-proof examining room of the Copifyer Lithograph Corp., Cleveland, Ohio, colored fluorescent lamps are used for inspecting color printing proofs. Yellow proofs, difficult to examine under white light, have strong contrast when inspected under a saturated blue light, which makes the yellow ink appear black. Similarly the red proof turns dark with light from a green fluorescent lamp; a blue proof is easy to examine under a pink fluorescent lamp with a light-red filter. The booth shown contains filtered red, blue and green lamps, yellow and standard white lamps, all individually controlled by switches. Photo courtesy of General Electric Co., Nela Park, Cleveland, Ohio.

Lighting An Apartment Bedroom

LIGHTING OBJECTIVE: To provide high level, low brightness illumination for reading in bed and make-up, and to achieve a feeling of warmth and sunshine in a small room having little daylight.

General Information: The room is 10'6" x 11'3" with a 9' ceiling. Rug and woodwork (including bedhead cabinet) are light grey, and the walls are painted a sunny yellow (70% RF). To increase the apparent size of the room, draperies, curtains, and bedspread were selected to match the wall color. Sheer yellow nylon curtains cover the two windows, while yellow and grey chrevron fabric hung on the wall beyond the windows gives the effect of wall-to-wall windows. Color accents are provided by three Kodachrome prints which are predominantly blue.

Lighting Installation:

1. *Bed* — Two 30-watt standard warm fluorescent lamps with a polished reflector are installed in a shelf-like unit in a

(over)

Installation at East Cleveland.

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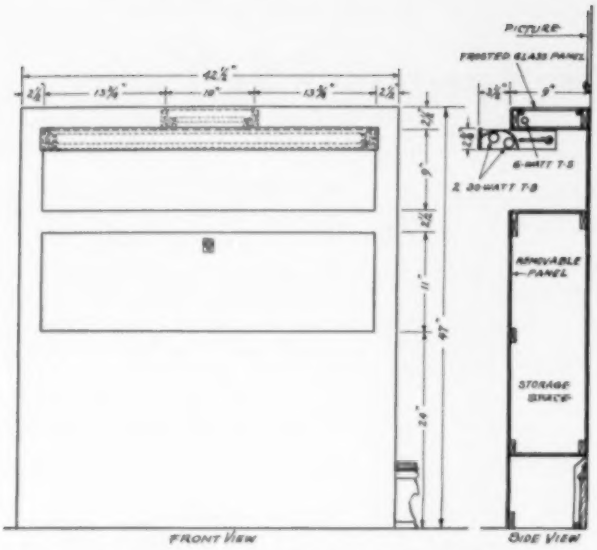

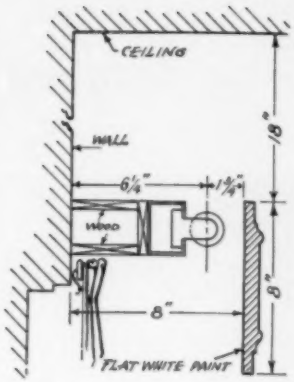

↑ *Detail of valance lighting.*

← *Detail of bed lighting.*

cabinet at the head of the bed. This unit can be pushed back flush with the cabinet or pulled out 3½" to provide a wider distribution of light.

In the center of the cabinet top a 6-watt fluorescent lamp is mounted below the front edge of a 6" x 10" piece of frosted glass. This illuminates the picture above the cabinet and also serves as a comfortable night or sick-room light.

2. *Dresser mirror* — A pair of 15-watt shielded fluorescent wall brackets (Moe-Bridges #8-115PL, not shown in illustrations) mounted 38" apart and 55" above the floor provide light for make-up.

3. *Valance* — An 8" wide wall-to-wall valance painted yellow to match walls and curtains conceals one 20-watt and two 40-watt standard warm fluorescent lamps in wiring channel (Garcy Adda-Strip #8000) mounted as indicated above.

4. *Ceiling* — General illumination is provided by a semi-indirect luminaire (Lightolier #7668) using five 40-watt filament lamps.

Illumination levels 18 months after installation are as follows:

Reading plane at bed	
(12" x 14" at 45° angle)	min. 55 ft-c
	max. 75
	avg. 66
General room average	
(30" plane, all lamps on)	12
Mirror	20-25

With reading light and valance on, brightnesses as viewed from reading-in-bed position are as follows:

Brightest spot just above valance	90 ft-L
Valance board	13
Brightest spot just below valance	84
Halfway from valance to floor	8
Ceiling above valance	
1 ft from wall	63
2 ft from wall	44
3 ft from wall	25
Bed cover, foot of bed	8

Lighting data submitted by Miss Aileen Page, Home Lighting Specialist, General Electric Lighting Institute, Nela Park, Cleveland, Ohio, as one solution of a lighting problem and to aid in the design of similar installations.

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TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Summary of Discussions and Actions, March Executive Meeting

The Society's Council Executive Committee held its bi-monthly meeting at the Engineers Club, New York City, March 8. Vice-President Hibben presided in the absence (on his visit to the Society's Regions) of President Sturrock. Present also were: E. M. Strong, Vice-President; A. H. Manwaring, General Secretary; A. D. Hinckley, Executive Secretary; C. L. Crouch, Technical Director; Emil W. Lampert; Carroll L. O'Shea; E. H. Salter, and M. N. Waterman.

Membership

Action was taken on the recommendation of the General Board of Examiners to elect to Society Membership 98 Members and 20 Student Members, a complete list of which is published at the end of the Telecast Section. Other changes in membership bring the current totals to the following:

September 30, 1950		March 8, 1951
7057	Total Membership	7239
32	Members Emeritus	34
41	Fellows	42
1610	Members	1665
5005	Associate Members	5188
369	Student Members	310

Local Activities

E. M. Strong, Chairman, reported on several local activities undertaken by Sections and Chapters. On his recommendation, action was taken authorizing the General Secretary to arrange for the manufacture and distribution of the Society emblem in Canada, to eliminate the problem of the payment of a considerable customs duty and tax on the part of Canadian members.

Professor Strong also reported on steps being taken to request the co-operation of the Lighting Education Committee in listing of films for circulation to the Sections and Chapters for use at meetings.

In a further discussion on Past-Chairman Awards, action was taken to make the Society's appreciation certificates available to the Sections and Chapters upon request for presentation to Past-Chairmen and to National Officers of the Society, such as Regional Vice-Presidents, etc., the expense of these certificates to be included in the headquarters budget.

An interesting I.E.S. Student Branch project was reported, in the undertaking by the City College of New York to study and measure specular reflection from various papers and inks. The C.C.N.Y. Branch is now considering this, and other projects which will be outlined by the Technical Committee Forum. C. L. Crouch, Technical Director, agreed to serve as a clearing agent for such information.

By Action of the Committee, Student Members are to be placed hereafter on a fiscal year basis, rather than an anniversary basis dating from their membership election, effective October 1, 1951. Student Members will be subject to the same By-Laws relating to delinquency as all other grades of membership.

Protective Lighting Clinic For Industrial Plant Safety

A clinic on protective lighting as an aid to industry in the prevention of sabotage, theft and accidents, was held February 15 in Chicago. Sponsored jointly by the Chicago Lighting Institute, the Chicago Association of Commerce and Industry and the Chicago Section of I.E.S., the clinic consisted of a morning and an afternoon session.

Chairman of the morning session was Colonel Walter F. Furbershaw, World War II Director of Military Intelligence, Sixth Service Command, U. S. Army, who is currently serving as Security Consultant and Vice-Chairman of the Plant Protection Committee of the Chicago Civil Defense Corps. Topics and speakers for this session were:

Planning Chicago's Plant Protection —Frank V. Martinek, Chairman, Plant Protection Committee, Chicago Civil De-

A CLINIC for protective lighting for industrial plants was given in Chicago February 15, sponsored jointly by the Chicago Lighting Institute and the Chicago Association of Commerce and Industry.

fense Corps, told of plans to prevent sabotage and espionage in the Chicago industrial area.

Light Sources for Protective Lighting —R. J. Diefenthaler, District Lighting Engineer, General Electric Co., discussed the use of incandescent spot and flood lamps and mercury-vapor lamps in protective lighting systems.

Area Protection Lighting — James C. Weeks, Lighting Application Engineer, Westinghouse Electric Corp., warned of the need for properly engineered lighting for authorized and unauthorized entrances and approaches, material storage, stock piles, storage tanks, water fronts, and internal roads.

The afternoon session, presided over by B. J. Martin, Editor and Publisher of *Electrified Industry*, covered the following subjects:

Area Protection Lighting — A. E. Swedenborg, Central Division Sales Manager, Benjamin Electric Mfg. Co., discussed methods of illumination as a positive aid to plant guards in the prevention of sabotage.

Protection Lighting Maintenance — Gordon Fowler, Public Service Co. of Northern Illinois, outlined maintenance methods and equipment to keep the protective lighting system in good operating condition.

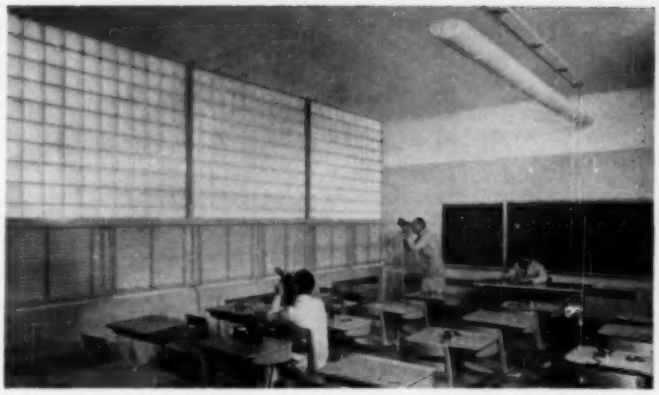
Protection Through Inspection — Carl F. Jensen, District Lamp Engineer, Westinghouse Electric Corp., spoke on the use of lighting for the protection and surveillance over drawings, equipment and employee identification.

The clinic, held in the auditorium at the Chicago Lighting Institute, 37 S. Wabash Ave., was attended by 236 representatives of industrial plants, equipment manufacturers, utility companies, engineers, contractors and wholesalers. The sponsors intend to repeat the program in the near future, since this response indicates a widespread interest.

Historic Quebec Is Site For Canadian Regional Conference

The internationally famous Chateau Frontenac in Quebec City will be the center of activities at the Canadian Regional Conference, May 9 through 11. Advance notice indicates a full program of technical sessions featuring fourteen topics and, for off-duty hours, entertainment ranging from tours of this historic city and such nearby points of interest as Montmorency Falls, St. Anne de Beaupre and the Island or Orleans to a "habitant-style" dance.

I.E.S. President Walter Sturrock will be on hand to address the members and the Council Executive Committee meeting is scheduled for the first day.



MODEL CLASSROOM on the rooftop of Engineering Building at University of Michigan permits testing of fenestration system under actual daylight conditions. Here Dr. Boyd (center) and assistants measure and record surface brightness of the panels of light-directing glass block while light meters on desks record light intensities on automatic tapes. In this view of the room, blinds are drawn over vision strips on the south wall in a test for light from glass block only. The chalkboard wall may be removed for west exposure investigation, and the ceiling raised or lowered for varying ceiling heights.

Daylighting Research Underway at U. of Michigan

Results of research on prism design of glass block and daylighting of classrooms were demonstrated for the first time March 13 at the University of Michigan Daylighting Laboratory, Ann Arbor, Michigan. The demonstration meeting was held for a representative group of 22 magazine editors.

Complete details of the daylighting studies, including description of the laboratory, measurement procedures and development of laboratory equipment, as well as full details of the results, have been outlined in a 96-page bulletin recently published by the University of Michigan. This is Engineering Research Bulletin No. 32, "The Development of Prismatic Glass Block and the Daylighting Laboratory" available from the Engineering Research Institute of the University of Michigan, Ann Arbor, at one dollar a copy. The report climaxes ten years of study and development work by Dr. R. A. Boyd, research physicist, and his associates, under the sponsorship of American Structural Products Co.

The Laboratory, its principal purpose the study of light-diffusing and light-directing glass block in the field of fenestration, has also reported interesting data concerning window arrangement and materials, reflectivity values of various color schemes, and the transmission of daylight under various room and weather conditions.

The Laboratory, built on the roof of the Engineering Building, consists of a testing section, painted flat black to diminish scattered light, which offers an artificial sun and sky plus auxiliary equipment for calibration and measurement purposes. In addition there is a model classroom with an adjustable ceiling and movable walls to study the properties of the fenestration under actual daylight conditions. The laboratory "sun" can simulate daylight conditions in any season in any geographical location at any time of the day, all by remote control. It consists of a 5000-watt projector equipped with a fresnel lens to provide a collimated beam of light.

For computing illumination and brightness values in the model classroom, a series of photocell devices have been developed in connection with the investigations. These include an exterior light meter to check sun and sky conditions, a direct-reading brightness meter developed in the Laboratory, to measure the brightness of the prismatic glass block panels, and a reflectometer (another Laboratory product) which appraises the amount of light reflected from wall and work surfaces to check brightness contrasts. Full description of the instruments used by Dr. Boyd in his studies, is also included in the Bulletin No. 32 describing the research.

Advanced Lighting Course Sponsored by New England Section

A course in advanced lighting applications, for those with background and experience who want to keep abreast of technical improvements and changing conditions, has been given, sponsored jointly by the New England Section of I.E.S. and the Electric Institute of Boston. Program chairman, Henry A. Klopot, Chairman of the Education Committee of the New England Section, provided the following program:

March 13 — Making Lighting Layouts and Calculations, R. G. Slauer, Sylvania Electric Products, Inc.

March 20 — Lighting for Production, E. A. Linsday, General Electric Co.
New Ideas on Maintenance, Fred. J. Vorlander, Champion Lamp Works

March 27 — Application of Color and Brightness Ratios, H. L. Logan, Holophane Co., Inc.

April 3 — Protective Lighting, Don T. Carter, General Electric Co.
Recreation Lighting, H. N. McIntyre, General Electric Co.

April 10 — School Lighting, Dr. Rexford Souder, Asst. Supt. of Schools, Brookline, Mass.
Hospital and Office Lighting — W. W. Thompson, Thompson Engineering Co.

April 17 — Lighting for Transportation, Eugene W. Beggs, Westinghouse Electric Corp., Lamp Division

Approximately 150 attended the sessions, which were held at the Hotel Touraine in Boston.

Five Clinics on Protective Lighting Launched in Cleveland

The first of five practical clinics on productive and protective lighting for industrial plants was held March 6 in Cleveland, sponsored jointly by the Cleveland Section of I.E.S., the Cleveland Electric Illuminating Co., and the Electrical League of Cleveland. The down-to-earth practical lighting clinic was attended by over 80 interested industrial plant and illuminating engineers.

Speaker at the opening clinic was Lt. Col. B. A. Saholsky, Chief of Cleveland Ordnance District. Col. Saholsky emphasized the importance of lighting in the production and protection in plants engaged in defense work. He noted that many plants in his district, formerly used for storage, are relighting for production areas, in order to produce over 290 million dollars worth of defense contracts in the Cleveland area.

With proper security of these plants, and the development of a protective lighting system throughout, a major lighting problem, the five clinics on "how-to-do" are expected to be a valuable contribution to Cleveland industry.

Telecast continued on page 9A

LIGHTING CALENDAR

Society Events

April 9-10, 1951 — Southern Regional Conference, Atlantis Hotel, Miami Beach, Fla.

May 9-11, 1951 — Canadian Regional Conference, Chateau Frontenac, Quebec City, Que.

May 18-19, 1951—Midwestern Regional Conference, Blackhawk Hotel, Davenport, Iowa

May 24-25, 1951 — Great Lakes Regional Conference, Hotel Gibson, Cincinnati, Ohio

June 14, 1951 — Meeting of I.E.S. National Council, New York, N. Y.

August 27-30, 1951 — Illuminating Engineering Society, National Technical Conference, Hotel Shoreham, Washington, D. C.

September 9-13, 1952 — Illuminating Engineering Society, National Technical Conference, Edgewater Beach Hotel, Chicago, Ill.

Industry Events

April 17-19, 1951 — American Society Mechanical Engineers Industries Division Conference, Lord Baltimore Hotel, Baltimore, Md.

April 23-25, 1951 — National Academy of Sciences, Washington, D. C.

April 28, 1951—American Trade Association Executives, Spring Meeting, Mayflower Hotel, Washington, D. C.

April 30 - May 2, 1951 — Chamber of Commerce 39th Annual Meeting, Washington, D. C.

April 30 - May 2, 1951 — The Spring 1951 Convention of the Society of Motion Picture and Television Engineers, Hotel Statler, New York, N. Y.

April 30 - May 2, 1951—American Institute of Decorators 20th Annual Convention, Pantlind Hotel, Grand Rapids, Mich.

April 30 - May 4, 1951 — National Materials Handling Exposition, International Amphitheatre, Chicago, Ill.

May 7-11, 1951 — National Fire Protection Association, Annual Meeting, Hotel Statler, Detroit, Mich.

May 9-11, 1951 — The Engineering Institute of Canada, Annual Meeting, Mt. Royal Hotel, Montreal, Canada.

May 10-11, 1951 — Electrical Contractors Association, Annual Convention, Royal York Hotel, Toronto, Can.

May 17-19, 1951 — Public Utilities Advertising Association, Hotel New Yorker, New York, N. Y.

May 20-23, 1951 — National Office Management Association, Hotel Commodore, New York, N. Y.

Week of May 20th, 1951 — National Association of Electrical Distributors, Atlantic City, N. J.

May 27-30, 1951 — American Society of Refrigerating Engineers, 38th Spring Meeting, Hotel Statler, Detroit, Mich.

May 28-30, 1951 — Conference on Electrical Instrument Design, London, England

May 28 - June 8, 1951 — Canadian International Trade Fair, Toronto, Can.

June 3-8, 1951 — Society of Automotive Engineers, Summer Meeting, French Lick Springs Hotel, French Lick, Indiana

June 4-7, 1951 — Edison Electric Institute, 19th Annual Convention, Denver, Colo.

June 6-16, 1951—British Plastics Exhibition and Convention, National Hall, Olympia, London, England

June 11-15, 1951 — Second Annual Conference on Industrial Research, Columbia University, New York, N. Y.

June 11-15, 1951 — American Society Mechanical Engineers, Semi-Annual Meeting, Royal York Hotel, Toronto, Canada

June 14-16, 1951 — National Society of Professional Engineers, Annual Meeting, Minneapolis, Minn.

June 18-20, 1951 — Annual Convention of the Canadian Electrical Association, St. Andrews, N. B.

June 18-22, 1951 — American Society for Testing Materials, Annual Meeting, Atlantic City, N. J.

June 25-29, 1951 — Summer General Meeting, American Institute of Electrical Engineers, Royal York Hotel, Toronto, Canada

June 25 - July 4, 1951 — International Commission on Illumination, Stockholm, Sweden

June 30 - July 7, 1951 — New York State Association of Electrical Contractors and Dealers Annual Convention, Saranac Inn, Saranac, N. Y.

July 2, 1951 — International Organization for Standardization, Geneva, Switzerland

July 2-4, 1951 — The American Society of Heating & Ventilating Engineers, Semi-Annual Meeting, Portland, Oregon

September 11-20, 1951 — Building Research Congress, London, England

September 25-28, 1951 — Fall Meeting, The American Society of Mechanical Engineers, Minneapolis, Minn.

October 8-12, 1951 — 39th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

October 9-12, 1951 — National Electrical Contractors Associations, Annual Convention, Shoreham Hotel, Washington, D. C.

October 15-17, 1951 — International Association of Electrical Inspectors, Southern Section, 23rd Annual Meeting, Hotel John Marshall, Richmond, Va.

October 15-19, 1951 — Fall 1951 Convention of the Society of Motion Picture and Television Engineers, Hollywood-Roosevelt Hotel, Hollywood, Calif.

October 22-26, 1951 — American Institute of Electrical Engineers, Fall General Meeting, Hotel Cleveland, Cleveland, Ohio

November 12-15, 1951 — National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

November 25-30, 1951 — Annual Meeting, The American Society of Mechanical Engineers, Atlantic City, N. J.

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New York City

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PYREX

I.E.S. Membership Roster To Be Available Soon

Compilation and publication of a complete membership directory is underway at headquarters office. It is planned to make this, as completely as possible, a business directory listing company connections rather than home addresses. Several mailings of a questionnaire have been necessary to obtain the business address.

The printed roster will be available from headquarters at $2.00 per copy, about May 1st.

Preprints of I.C.I. Papers Available from National Committee

Preprints of the reports and technical papers to be presented at the twelfth meeting of the International Commission on Illumination, June 26 to July 5, in Stockholm, Sweden, are now available in two volumes, priced at approximately $3.30 per volume, individual papers may be ordered at about 25c each. Preprints should be ordered from Louis E. Barbrow, Secretary of the U. S. National Committee, I.C.I., at the National Bureau of Standards, Washington, D. C.

Following the I.C.I. Congress, it is expected to have copies of these preprints for sale at the National Technical Conference of the I.E.S.

Metallurgical Advisory Board Is Organized

Formation of a board of leading industrial and academic metallurgists to advise the Research and Development Board, Department of Defense, on research aspects of some of the nation's most critical metals problems has been announced. Preliminary work is already in progress on research and development phases of three of the most urgent metals problems: critical and strategic metals and their substitutes, the application of metals to be used at high temperatures and the development of the presently small titanium industry.

Among the metals in critically short supply listed for study are three which are important to the lighting industry: molybdenum, tungsten and beryllium.

The board, which is organized by the National Academy of Sciences - National Research Council has as Executive Director, V. H. Schnee, vice-president of the University of Oklahoma and director of the university's Research Institute. Dr. Zay Jeffries, retired vice-president of the General Electric Co., will head the activities on critical and strategic metals and their substitutes.

AN ADVANCED LIGHTING course has been given, in six weekly sessions, by the Pittsburgh Section of I.E.S. in cooperation with the Electric League of Western Pennsylvania.

Annual Advanced Lighting Course Given by Pittsburgh Section

Six two-hour weekly sessions in advanced lighting, sponsored by the Pittsburgh Section,, I.E.S. in cooperation with the Electric League of Western Pennsylvania, have become an annual event for engineers, sales representatives, contractors and architects in the area to keep in step with advanced theory and practices. The 1951 course, organized by the Section's Education Committee, consisted of the following classes:

February 26, 1951 — Daylighting, utilization and application: Leader, R. W. McKinley, Pittsburgh-Corning Corp.

March 5, 1951 — Low Brightness Lamps and Their Applications; Leader, James A. Hodges, Busch-Hodges Co.

March 12, 1951—Luminous Ceilings, Characteristics and Applications; Leader, Charles W. Carr, Wakefield Brass Co.

March 19, 1951—Fluorescent Lamp Ballasts, Their Circuits, Operation and Characteristics Affecting Lamp Operation and Life; Leader, Gordon Harvey, General Electric Co.

March 26, 1951—What a Consulting Engineer Looks for in Lighting Equipment with Respect to Performance, Construction, Appearance; Leader, James Paul Warner, Consulting Engineer.

April 2, 1951 — Industrial Lighting Applications, Problems and Practices: Leader, P. M. Hixson, American Cyanamid Corp.

A total of 42 representatives of the local lighting industry were enrolled for the course, which was held at 600 Grant Street, Pittsburgh.

Young Engineers Win Award

The Eta Kappa Nu Recognition Award winners for the 1950 outstanding young American electrical engineers have been announced. Donald P. Campbell, professor at the Massachusetts Institute of Technology, is the winner. Three Honorable Mentions were also awarded. These were:

Andrew W. Edwards, Westinghouse Electric Corp.
Kenneth A. Kesselring, Knolls Atomic Power Laboratory
Robert W. Mayer, General Electric Company

Eta Kappa Nu established these awards in 1936 to recognize, each year, young electrical engineers for "meritorious service in the interest of their fellow men."

IT SEEMS TO ME

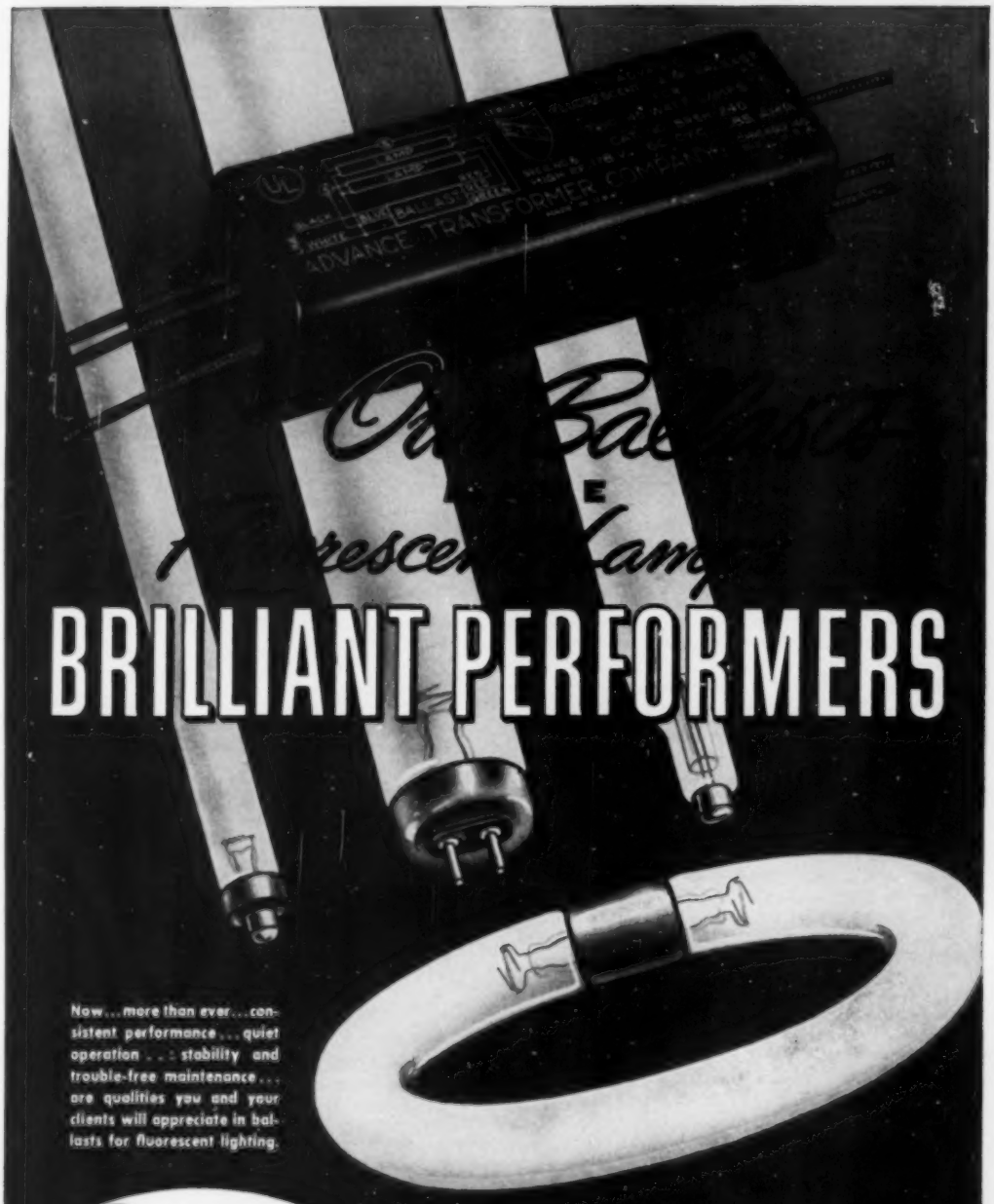
Army Seeks Illuminating Engineers

To the Editor:

The importance of illuminating engineering to the National Defense effort is growing by leaps and bounds as night becomes the favorite battle period for our present and potential enemies.

The Mechanical and Electrical Engineering Department of the Engineer Research and Development Laboratories has the sole responsibility for developing illumination equipment for battle use. This activity has been at low ebb since the

Continued on page 11A



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Continued from page 9A

end of World War II, primarily because funds and military support were lacking. Almost over night, both funds and support have been given to the program with the directive that no time is to be lost in getting suitable battlefield illumination equipment to our troops.

It will be no surprise to you, I am sure, that the major problem is one of qualified personnel. We do not have sufficient trained illuminating engineering personnel here at these Laboratories to do this job. I am, therefore, appealing to the Illuminating Engineering Society. Among the members and student members of your organization there are probably men who are willing to contribute their skill to this program. I would appreciate your encouraging them to write to me for further details regarding the vacancies available.

Briefly, the activity centers around the development of classified, large area illumination equipment, either as separate units or as attachments to fighting vehicles of various types. Basic research and practical design are both involved, including light source and development and test, photometric evaluations and field testing. All positions come under Civil Service regulations and are civilian in character.

Any assistance which you may be able to give us in finding applicants will be an important contribution to the National Defense effort. — LT. COL. OSCAR P. CLEAVER, *Chief, Mechanical and Electrical Engineering Department, Engineer Research and Development Laboratories, Fort Belvoir, Va.*

Installations to See When You Visit Cincinnati

Installation	Address	Interesting Feature
Baynham's Shoes, Inc.	431 Vine	Combination fluorescent, incandescent and luminous ceiling
C. G. & E. Co. (Lobby and Mezzanine)	4th & Main	Combination of louverall ceiling, downlights and fluorescent lensed troffers
Terrace Plaza Hotel	6th & Vine	Incandescent and fluorescent — multiple small wattage recessed downlights and special design fluorescent luminaires
Union Central Life Insurance Co.	4th & Vine	Fluorescent troffers
Cincinnati Gardens Inc.	2250 Seymour	Special sports lighting effects—three-lamp cluster industrial downlights and incandescent troffers
Liberal Savings & Loan Co.	530 Main	Recessed fluorescent troffers
Mabley & Carew Co. 4th & 5th Floors	5th & Vine	Fluorescent
Tyler Davidson Fountain	Fountain Square	Underwater incandescent
J. C. Penny Co.	6th & Race	Incandescent and special fluorescent slimline commercial luminaires
Newberry Five & Ten	6th & Race	High intensity fluorescent
Ohio National Insurance Co.	2400 Reading	Continuous fluorescent
Minute Chef	19 East 4th	Incandescent downlights and cove lighting
Crosley Field	Western & Freeman	Incandescent floodlighting

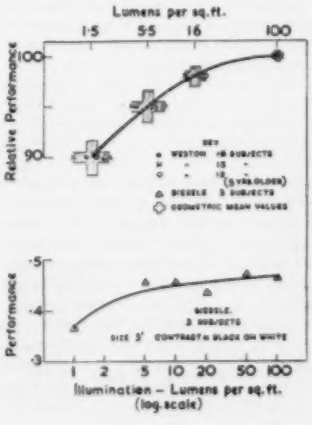
NOTE: Personnel of the Lighting Division of the Cincinnati Gas & Electric Co. will arrange any special trip which visitors to the city may care to see.

Task-to-Surround Brightness Ratios

To the Editor:

I have read with interest the paper on Effect of Task-to-Surround Brightness Ratios on Visual Performance, by Professor R. L. Biesele, which appeared in the December 1950 issue of ILLUMINATING ENGINEERING.

In the discussion on this paper, Dr. Gertrude Rand Ferree points out that, even though the results obtained by the author of the paper, and plotted in his Fig. 6, include action time and do not take account of accuracy, the average performances of the three observers show a relation between illumination and performance very similar to that found by me for the same size and contrast. I have plotted the average performance (as reciprocal of time in seconds per ring marked) of Biesele's three subjects at each illumination level in the accompanying graph, and have fitted a smooth curve to the points. From this curve the illuminations which give various percentages of the maximum performance can be found, and these are indicated in the upper part of the diagram for comparison with the illuminations found in my investigations. The agreement of Biesele's findings with my own is, I think, as good as might be expected in view of the differences in number of observers and method of scoring the performance. The agreement would be even closer if the curve to Biesele's points were made flatter over the range 5 to 100 lumens per square foot, as it well might be.



It is also of interest to note that Professor Biesele's results, as presented in his Fig. 5, indicate that performance is best, not when the luminance of the surround is equal to that of the task, but when the task has a luminance value of from two to ten times that of the surround. Lythgoe's classical work on visual acuity showed this, though his work has often been misinterpreted to support the fictitious ideal one-to-one ratio of task-to-surround luminance. — H. C. WESTON, *Group for Research in Occupational Optics, Institute of Ophthalmology, London, England.*

Publications Available

To the Editor:

We have a collection of the bound Proceedings of the National Electric

Light Association which we would be glad to send gratis wherever there is a need for volumes for the completion of sets. These are:

1909—32nd Convention—Vols. I, II, III (2 copies each)
1910—33rd Convention—Vol. II
1911—34th Convention—Vols. I, II
1912—35th Convention—Vols. I, II, III
1913—36th Convention—2 Vols.; General, Commercial
1914—37th Convention—2 Vols.; General Commercial
1915—38th Convention—1 Vol.; Commercial
1916—39th Convention—4 Vols.; General, Commercial, Technical and Hydro-Electric, Accounting
1917—40th Convention—2 Vols.; Proceedings of the War Convention, General; Commercial
1918—41st Convention—1 Vol.; Proceedings of the 2nd War Convention
1920—43rd Convention—1 Vol.; Convention Proceedings (2 copies)
1921—44th Convention—Vols. I, II
1922—45th Convention—Vols. I, II (2 copies each) Also 2 Vols.; General, Commercial (2 copies each)
1923—46th Convention—Vol. 79 (2 copies), Vol. 80 (2 copies)
1926—49th Convention—Vol. 83
1927—50th Convention—Vol. 84
1928—51st Convention—Vol. 85
1929—52nd Convention—Vol. 86
1930—53rd Convention—Vol. 87
1931—54th Convention—Vol. 88
1932—55th Convention—Vol. 89

Thank you for making this information available to your readers. — HELEN A. HOFFMAN, *Engineering Division, The Hoover Co., Canton, Ohio.*

OBITUARIES

Rudolf W. Staud

Rudolf W. Staud

Rudolf W. Staud, one of the industry's best-known figures, and Past-President of the Illuminating Engineering Society, died March 28 at the age of 59 in Chicago, following an illness of two weeks.

It is characteristic of Mr. Staud's energetic service to the lighting industry that almost every large association serving it will mourn the passing of its leader. In addition to especially active service to I.E.S., Mr. Staud was (since its inception in 1936) President of the R.L.M. Standards Institute, Treasurer of the U. S. National Committee of I.C.I., a Director of the Chicago Lighting Institute and an officer of the National Electrical Manufacturers Association.

His activities have benefited and will continue to benefit for many years, almost every phase of lighting practice. He was a leader in the movement toward national specification-certification in the industrial lighting equipment field, an instigator and heavy contributor toward the success of the International Lighting Expositions, Editor of *The Lighting Review and Digest* — to name a few of his activities with long-lasting value.

Mr. Staud's services to the Illuminating Engineering Society were of similar worth. His work for the Society, on many committees and in many offices, characteristically did not cease after his term as President, but continued and grew. At the time of his death he was a guiding influence of the Society's journal, ILLUMINATING ENGINEERING; and Chairman of the Task Committee on Advertising Sales of the Publications Committee, Board of Nomination, Sub-Committee on Advertising Sales of Publications Committee, and Member of Medal Award Committee, Research Fund Committee, and the Publications Committee.

Joseph W. Fleming, manager of the Technical Information center for Philips Laboratories, Inc., was killed in an automobile accident, February 12, near his home in Edgewater, N. J.

Before joining Philips in 1946, Mr. Fleming was associated with the National Broadcasting Co. and American Broadcasting Co. He served overseas in World War II as technical adviser to the U. S. Air Force in Europe and the Royal Air Force.

In addition to active service with the Illuminating Engineering Society, he was a member of many other technical and professional societies, including the Fluorescent Lighting Association, American Society for Testing Materials, Armed Forces Communications Association, Institute of Radio Engineers and the American Society for Quality Control.

Frank A. Hansen, Fellow and Member Emeritus of the Society, died March 9 at his home in Los Angeles. Mr. Hansen had been a tireless worker for I.E.S. since his election to membership in 1926. After service in the Navy during World War I, Mr. Hansen was field engineer for the Holophane Co. until 1933. In 1934 he founded the Western Institute of Light and Vision and was managing director of that organization until his death. He was author of the dimout and

Frank A. Hansen

blackout regulations for the West Coast during World War II and wrote two books on the subject of lighting, "Seeing" and "Your Home," which have been used throughout the United States.

Greatly respected in his local Section which he served as Chairman from 1927 to 1930, Mr. Hansen was also especially active in the Society's national committees. He further served the Society nationally as a member of Council as Vice President for the South Pacific Coast Region from 1940 to 1943.

In recognition of his valued service to illuminating engineering he was elected to the grade of Fellow in 1946 and was Chairman of the Board of Fellows, 1948-1949. Upon his retirement in 1950, Mr. Hansen was elected Member Emeritus of I.E.S.

ABOUT PEOPLE

Election of **Hoyt P. Steele,** executive vice-president of Benjamin Electric Manufacturing Co., as a director of the American Standards Association, has been announced.

Mr. Steele is chairman of the I.E.S. Papers Committee and member of the Technical Conference Committee. He is also a member of the Board of Governors of the National Electrical Manufacturers Association and a member of the Technical Committee of the Reflector and Lamp Manufacturers Standards Institute.

Dr. E. C. Crittenden, recently retired from the National Bureau of Standards, and **Richard E. Simpson,** Consulting Engineer, were elected to the grade of Member Emeritus of I.E.S. at the February 8 meeting of Council. The election was made on the recommendation of the General Board of Examiners, in recognition of their many years of service to the Society.

George S. Evans, director of Westinghouse fluorescent lamp engineering

since 1948, has been named manager of commercial engineering for the Westinghouse Lamp Division, Bloomfield, N. J. Mr. Evans succeeds the late Ralph R. Brady as head of commercial engineering, which serves as a liaison between the lamp engineering, manufacturing and sales departments. Mr. Evans has been in the company's research, engineering and production departments — working mostly with gaseous discharge devices such as lamps and electronic tubes — since he entered as a member of its graduate student course in Pittsburgh, Pa., fifteen years ago.

A member of the I.E.S. Committee on Light Sources for the past three years, Mr. Evans has presented papers on fluorescent lamps at the National Technical Conferences.

The Lighting Institute at Nela Park has been established as a separate division of General Eectric's Lamp Department, and **Henry J. Chanon** has been appointed its first manager. In the past the Institute has been an activity of the Engineering Division. Mr. Chanon comes to his new position from the Lamp Department's Buckeye Sales District in Cleveland.

Dr. Rolland M. Zabel has been appointed manager of engineering for the Westinghouse Lamp Division, Bloomfield, N. J. and will direct all the division's lamp engineering and development, its chemical and metallurgical engineering and the activity of its experimental factory. Dr. Zabel is an active member of I.E.S., is Chairman of the Committee on Street and Highway Lighting, member of the Technical Papers Committee, and representative to the President's national safety committee.

The Board of Directors of the Westinghouse Electric Corporation elected four new vice-presidents at the January board meeting. These are **Tomlinson Fort**, manager of the headquarters apparatus sales department; **L. W. McLeod**, southwestern district manager; **Emery W. Loomis**, middle Atlantic district manager; and **L. E. Lynde**, who will now head the company's Washington, D. C. office.

John W. Belanger and **Nicholas M. DuChemin** have been named general managers of the Large Apparatus Divisions and Small Apparatus Divisions, respectively, of the General Electric Company's Apparatus Department. The appointments mark an integration of the department into three basic units: the Large and Small Apparatus and a Marketing Division, which will continue under **Chester H. Lang.**

New managers for two lamp works have been announced by General Electric Lamp Department. **W. M. Miller,** who has been head of the East Boston Lamp Works, has been appointed manager of the Mattoon Lamp Works, Mattoon, Ill. **R. F. Johnson,** from the staff of the Memphis Lamp Works, replaces Mr. Miller as manager in East Boston, Mass.

Bernard D. Levauer and **Dan E. Dunne** have been re-elected as Chairman and Vice-Chairman of the Industrial and Commercial Lighting Equipment Section of the National Electrical Manufacturers Association for the year 1951. Mr. Levauer is vice-president of the Pittsburgh Reflector Company and Mr. Dunne is vice-president of Lighting Products, Inc.

Ewart M. Haacke, formerly editor of leading Canadian magazine, "Electrical News and Engineering," has joined the J. A. Wilson Lighting and Display Ltd. as manager of their Montreal branch office.

BOOKS AND PAMPHLETS

Color Dictionary — A 64-page color dictionary has been published by Container Corporation of America, 38 South Dearborn Street, Chicago 3, Ill., as a supplement to the Color Harmony Manual. This dictionary contains 775 names so arranged that the user can work from names to colors or from colors to names. It is necessary only to select matching color chips from the Manual and then find the names in the dictionary corresponding to the notations on the chips. All names are the kind used to describe merchandise sold in the mass market.

A chart of reflectance values for both the dull and glossy sides of all the chips in the Manual is also available from the same company.

I.C.I. Publications — The stock of proceedings and other publications of the International Commission on Illumination has been transferred from London to the New York Central Bureau. Stock includes a small number of volumes of Proceedings, some booklets and pamphlets. These can be obtained from the New York Central Bureau, International Commission on Illumination, P. O. 1373, Grand Central Station Post Office, New York 17.

Traffic Engineering Handbook, edited by Henry K. Evans, published by the Institute of Traffic Engineers assisted by the Association of Casualty and Surety Companies, 1950; 520 5½ x 8½ inch pages, 205 tables, 215 illustrations; $6.00 (quantity prices quoted on request). This is a revised and expanded version of the 1941 edition of "the only comprehensive source book of techniques, principles and standards relating to street and highway traffic control and design." Topics treated include vehicle and highway statistics, vehicle motion, the driver and pedestrian, traffic accidents, traffic studies, traffic markings and markers, traffic signs and signals, parking and loading, roadway capacity and design, speed regulations, and street and highway lighting.

Of particular interest to lighting engineers are driver statistics, information on driver vision, and perhaps the chapter on pedestrian traffic. The 26-page lighting chapter, written by Henry W. Osborne with the assistance of the I.T.E. Committee on Street and Highway Lighting, is based on the 1947 "American Standard Practice for Street and Highway Lighting" but contains additional material on available types of lamps for street illumination, hours of sunrise and sunset in each state in U. S., with a concluding two-page section on instrumentation for the measurement of street illumination.

Out-of-Print Books — The American Library Service, 117 West 48th Street, New York 19, N. Y., announces that it is headquarters for all books which are out of print, on all subjects and in all languages.

See Your Home in a New Light is a new brochure containing an artist's conception of the application of "22 new recipes for better living in a better-lighted home." Designed to give information and guidance on what lighting equipment to use and where to place it, for each home seeing task, the booklet is available without charge from the General Electric Co., Lamp Department, Inquiry Bureau, Nela Park, Cleveland 12, Ohio.

The Eighteenth Annual Report of the Engineers' Council for Professional Development can now be obtained from the headquarters office, 29 West 39th Street, New York 18, N. Y. — price 50 cents. The 56-page booklet contains reports from the organization's committees; financial statements; lists of accredited undergraduate engineering curricula and accredited technical institute programs; officers, representatives and committee personnel; and a price list of publications available.

New Member Listing on page 20A

SUSTAINING MEMBERS

Acme Electric Corp.
Cuba, N. Y. *J. A. Comstock*

Advance Transformer Co.
1122 W. Catalpa Ave., Chicago 40, Ill. *Hirsch Epstein*

Alabama Power Co.
Birmingham, Ala. *George L. Morris*

All Bright Electric Products Co.
5917-25 N. Kedzie Ave.,Chicago 18, Ill. *Max Klein*

Aluminum Company of America
Gulf Building, Pittsburgh 19, Pa. *C. Braglio*

Amalgamated Electric Corp., Ltd.
384 Pape Ave., Toronto, Ont., Canada *D. W. Patterson*

American Concrete Corp.
4727 North Lamon Ave., Chicago 30, Ill. *J. W. Lewis*

American Fluorescent Corp.
5407 Broadway, Chicago, Ill. *William Rusnak*

American Sterilizer Co.
Erie, Pa. *Horace Wm. Alexander*

Appleton Electric Co.
1701-1729 Wellington Ave., Chicago 13, Ill. *Nils A. Tornblom*

Arkansas Power & Light Co.
Simmons National Bldg., Pine Bluff, Ark. *Max Sudduth*

The Art Metal Co.
1814 E. 40th St., Cleveland 3, Ohio *George E. Glatthar*

Bausch & Lomb Optical Co.
Rochester 2, N. Y. *Arthur E. Neumer*

Benjamin Electric Mfg. Co.
Des Plaines, Ill. *John H. Waterbury*

Blue Ridge Glass Corp.
P.O. Box 631, Kingsport, Tenn. *James Herbert*

Board of Water and Electric Light Commissioners
116 W. Ottawa St., P.O. Box 570, Lansing 3, Mich. *John D. Mainight*

Boston Edison Co.
39 Boylston St., Boston 12, Mass. *R. B. Brown, Jr.*

Branham, Mareck & Duepner, Inc.
7020 Walker St., St. Louis Park, Minneapolis 16, Minn. *Cecil H. Branham*

Bright Light Reflector Co., Inc.
Fairfield & State, Bridgeport 5, Conn. *R. J. Mott*

British Columbia Electric Rwy. Co., Ltd.
570 Dunsmuir St., Vancouver, B. C., Canada *H. N. Walters*

Brockton Edison Co.
36 Main St., Brockton 67, Mass. *W. A. Forbush*

Edward F. Caldwell & Co., Inc.
101 Park Ave., New York 17, N. Y. *E. T. Caldwell*

California Electric Power Co.
P.O. Box 512, Riverside, Calif. *W. E. Vaugen, Jr.*

Calpa Products Co.
4116 Chester Ave., Philadelphia 4, Pa. *Paul C. Calissi*

Cambridge Electric Light Co.
46 Blackstone St., Cambridge 39, Mass. *Reginald H. Bowman*

Canadian General Elec. Co., Ltd.
212 King St., Toronto, Ont. *R. M. Love*

Canadian Laco Lamps, Ltd.
745 Guy St., Montreal, Que. *J. Thomas*

Canadian Line Materials, Ltd.
Postal Station H, Toronto 13, Ont., Canada *L. E. Messinger*

Central Hudson Gas and Elec. Corp.
50 Market St., Poughkeepsie, N. Y. *H. E. Dexter*

Central Illinois Light Co.
316 Jefferson Ave. S., Peoria 2, Ill. *R. K. Dallas*

Central Illinois Public Service Co.
607 E. Adams St., Springfield, Ill. *B. L. Palm*

Central Maine Power Co.
9 Green St., Augusta, Maine *Roland W. Hess*

Central Power & Light Co.
P.O. Box 2121, Corpus Christi, Texas *James M. Williams*

Champion Lamp Works Div. of Consolidated Electric Lamp Co.
600 Broad St., Lynn, Mass. *Ellery H. Raddin*

Cincinnati Gas & Electric Co.
Fourth & Main Sts., Cincinnati 1, Ohio *J. R. Hartman*

Circlite Corp.
118 So. Clinton St., Chicago, Ill. *George Gomberg*

City of Burbank, California Public Service Dept.
174 W. Magnolia Boulevard, Burbank, Calif. *J. H. McCambridge*

City of Glendale Public Service Dept.
119 N. Glendale Ave., Glendale 6, Calif. *H. E. Gulick*

City of Riverside Electric Light Dept.
3854 Mulberry St., Riverside, Calif. *L. W. Grayson*

City of Seattle, Dept. of Lighting—Puget Sound
1015 Third Ave., Seattle 4, Wash. *P. C. Spowart*

City of Tacoma, Light Division
402 City Hall, Tacoma 2, Wash. *Roy H. Weston*

The Cleveland Electric Illuminating Co.
75 Public Square, Cleveland 1, Ohio *R. C. Hienton*

Clyde Porcelain Steel Corp.
2211 Birdseye St., Clyde, Ohio *W. F. White*

Colonial Premier Corp.
466 W. Superior St., Chicago 10, Ill. *Richard Weis*

Columbia Electric & Mfg. Co.
1024 West Ide Ave., Spokane, Wash. *Walter A. Toly*

Commercial Light Co.
841 W. Washington Blvd., Chicago, Ill. *Michael R. Fine*

Commonwealth Edison Co.
72 W. Adams St., Chicago 90, Ill. *Ralph G. Raymond*

The Connecticut Light & Power Co.
250 Freight St., Waterbury 91, Conn. *James H. Doak*

Consolidated Edison Co. of N. Y., Inc.
4 Irving Place, New York 3, N. Y. *Thomas J. Collins*

Consolidated Gas, Elec. Light & Power Co. of Baltimore
100 W. Lexington St.,Baltimore 1, Md. *M. C. Albrittain*

Consumers Power Co.
212 Michigan Ave. W., Jackson, Mich. *D. E. Karn*

Consumers Public Power Co.
1452 25th Ave., Columbus, Nebr. *W. H. Sinke*

Corning Glass Works
Corning, N. Y. *A. S. Tylor*

Coyne Electrical School, Inc.
500 So. Paulina St., Chicago 7, Ill. *John Hanan*

Crescent Electric Supply Co.
765 Iowa St., Dubuque, Iowa *Titus B. Schmid*

Crouse-Hinds Co.
Syracuse 1, N. Y. *A. H. Clarke*

Crouse Hinds Co. of Canada, Ltd.
7 Labatt Ave., Toronto, Ont. *F. R. Jeffery*

Curtis Lighting, Inc.
6135 W. 65th St., Clearing Station, Chicago 38, Ill. *Darwin Curtis*

Curtis Lighting of Canada, Ltd.
195 Wicksteed Ave.,Leaside, Toronto 12, Ont. *H. L. Wright*

Cutler Light Manufacturing Co.
2026-28 N. 22d St., Philadelphia 21, Pa. *Robert T. Cutler*

Dallas Power & Light Co.
1506 Commerce St., Dallas 1, Texas *W. G. Moore*

Day-Brite Lighting, Inc.
5401 Bulwer St., St. Louis 7, Mo. *D. J. Biller*

The Dayton Power & Light Co.
25 No. Main St., Dayton, Ohio *H. S. Nonneman*

Dazor Manufacturing Corp.
4483 Duncan Ave., St. Louis 10, Mo. *P. L. Read*

Delaware Power & Light Co.
600 Market St., Wilmington 99, Del. *W. A. F. Pyle*

Dept. of Water & Power, City of Los Angeles, Bur. of Power & Light
Box 3669, Terminal Annex, 207 So. Broadway, Los Angeles 54, Calif. *C. P. Garman*

Detroit Edison Co.
2000 Second Ave., Detroit 26, Mich. *L. E. Tayler*

Detroit Electrical Contractors Association
627-628 Hotel Book Cadillac, Detroit 26, Mich. *Carl J. Schoeniger*

Detroit Steel Products Co.
2250 E. Grand Blvd., Detroit 11, Mich. *W. Clifton Randall*

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Wilmington 98, Del. *S. W. Quisenberry*

E. I. duPont de Nemours & Co., Inc. Polychemicals Dept.
Wilmington 98, Del. *R. E. Leary*

Duquesne Light Co.
435 Sixth Ave., Pittsburgh 19, Pa. *G. W. Ousler*

Duro Test Corp.
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Eastern Fixture Co., Inc.
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East Side Metal Spinning & Stamping Corp.
1301 Elizabeth Ave., W., Linden, N. J. *M. A. Kremer*

Ebasco Services, Inc.
2 Rector St.,New York 6, N. Y. *M. E. Stone*

Efongee Electrical Supply Co.
671 W. Washington Blvd., Chicago 6, Ill. *Lee Mirus*

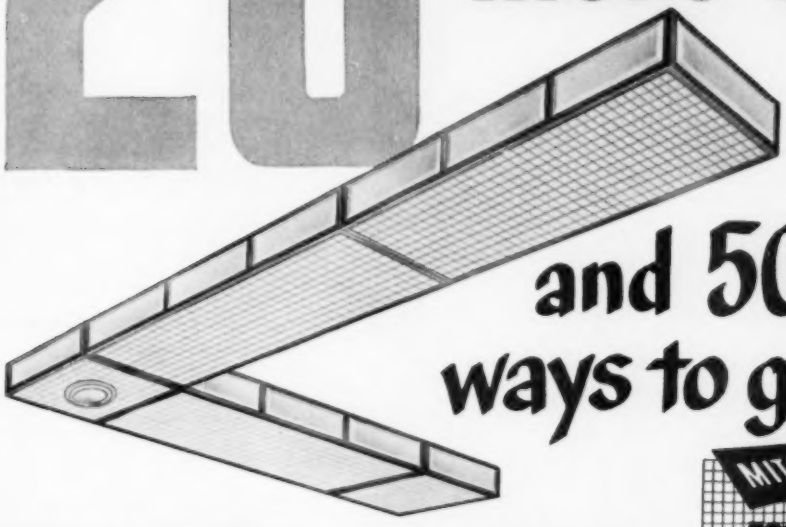
Electrical Information Publications, Inc.
20 N. Carroll St., Madison, Wis. *Lewis E. Johnson*

Electrical Testing Laboratories, Inc.
79th St. & East End Ave., New York City 21, N. Y. *W. F. Little*

(*Continued on page 16A*)

(*Note:* Names of Official Representatives appear in italics.)

20% more light



and 50,000 ways to get it

that's the lighting magic of MITCHELL **module**

REG. U. S. PAT. OFFICE

20% MORE LIGHT! This department store MODULE installation delivers 60 footcandles. To obtain the same light output with ordinary fixtures, 20% more units would be needed.

Yes, MODULE's exclusive Polystyrene plastic louver passes 20% MORE LIGHT than conventional metal louvers—saves more lighting dollars in *any* installation. And with just 4 simple, low-cost "building blocks of light," MODULE creates *unlimited* custom-fitting lighting patterns to fit *any* commercial interior. Because MODULE units fit together simply (both mechanically and electrically), patterns can be rearranged to suit changing needs—*at minimum cost.* MODULE's styling is enduring; stays beautiful, new. No ordinary fixtures can match MODULE—the *only* lighting system that delivers *20% more light,* that *custom-fits* any commercial installation at *lowest cost.*

20% MORE LIGHT! In this modern drug store, MODULE attains a 96 footcandle output. An equivalent number of conventional fixtures would deliver only 80 footcandles.

20% MORE LIGHT! Here is MODULE in an appliance store, delivering 70 footcandles. Using the same number of ordinary fixtures, only 58 footcandles would be obtained.

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Get your copy of MODULE IN ACTION showing actual installations. Here are selling ideas unlimited for contractors, architects, utility representatives and lighting salesmen. Write for your free copy today.

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2523 N. Clybourn Avenue • Chicago 14, Illinois

In Canada: Mitchell Mfg. Co., Ltd., 11-25 Davies Ave., Toronto

(Continued from page 14A)

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701 W. Jackson Blvd., Chicago 6, Ill.
L. B. Mangione

Electro Manufacturing Corp.
2000 W. Fulton St., Chicago 12, Ill.
L. K. Schoenbrod

Electrolier Mfg. Company, Ltd.
5849 Boyer St., Montreal, Que., Canada
John Issenman

Ender Manufacturing Corp.
260 West St., New York 13, N. Y. *Jules Levenstein*

Electron Corp.
5100 South Santa Fe, Littleton, Colo.
William H. Johnson

Englewood Electrical Supply Co.
5801-03 So. Halsted St., Chicago, Ill. *Ray O'Leary*

Fitchburg Gas & Electric Light Co.
537 Main St., Fitchburg, Mass. *A. G. Neal*

Florida Power & Light Co.
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Fluorescent Fixtures of Calif.
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Ernst O. Anders

Fluorescent Maintenance Co., Inc.
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Leonard K. Black

Fluores-O-Lite Co.
Evans Terminal, No. Broad St., Hillside, N. J.
Meyer H. Silverman

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Fostoria, Ohio *E. L. Bates*

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Stanley A. Framburg

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1425 Rockwell Ave., Cleveland 14, Ohio
Dave Frankel

Franklin Design Service, Division of Safeway Stores, Inc.
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27-01 Bridge Plaza North, Long Island City, N. Y.
Theo. J. Brassel, Jr.

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Frank A. Gallagher

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G. G. Harney

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River Works, 920 Western Ave., West Lynn, Mass.
A. F. Dickerson

General Electric Co., Lamp Dept.
Nela Park, Cleveland 12, Ohio *Willard C. Brown*

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W. W. Booth

General Lighting Products Co.
468 Frelinghuysen Ave., Newark 5, N. J.
Nathan H. Eglowstein

General Outdoor Advertising Co., Inc.
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Charles A. Collier

Gibson Manufacturing Co.
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R. R. Gibson

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Amber & Tioga Sts., Philadelphia 34, Pa.
C. A. Gill

Gillinder Brothers, Inc.
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Isidor Rosenblatt

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Golde Manufacturing Co.
1214 W. Madison, Chicago 7, Ill. *E. W. Goldberg*

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Kenneth C. Welch

Graybar Electric Co., Inc.
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3044 W. 106th St., Cleveland 11, Ohio
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Joseph T. Manucia

Heisleuline Co.
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2219 W. Grand Ave., Chicago 12, Ill.
I. M. Fixman

Hydro-Electric Power Comm. of Ont.
620 University Ave., Toronto, Ontario
Charles K. Lambka

Hyland Electrical Supply Co.
700 West Jackson Blvd., Chicago, Ill. *J. A. Tills*

Illinois Power Co.
154 East Main St., (L Box 511 B), Decatur 70, Ill. *Allen Van Wyck*

Illuminating Engineering Co.
2347 E. Nine Mile Road, Hazel Park, Mich.
Bert C. Pretzer

Iowa Electric Light & Power Co.
Box 351, Cedar Rapids, Iowa *Sutherland Dows*

Iowa-Illinois Gas & Electric Co.
United Light Bldg., Davenport, Iowa
John M. Hollingsworth

Iowa Power and Light Co.
312 Sixth Ave., Des Moines 3, Iowa
N. Bernard Gussett

Iowa Public Service Co., East Div.
400 Commercial St., Waterloo, Iowa
C. R. Wagoner

Iowa Public Service Co., Sioux City Division
P.O. Box 778, Sioux City 4, Iowa *C. R. Tracy*

Joannette Shade & Novelty Co.
N. Fourth St., Jeannette, Pa. *H. N. Crock*

Jefferson Electric Co.
Bellwood, Ill. *L. Mauerer*

Jersey Central Power & Light Co.
501 Grand Ave., Asbury Park, N. J. *D. J. Douglas*

Jolcco Corporation
2513 Baldwin St., St. Louis, Mo. *George Ledbetter*

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Joslyn Mfg. & Supply Co.
3700 So. Morgan St., Chicago 9, Ill. *J. H. Fahey*

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P.O. Box 679, Kansas City 10, Mo.
John M. Arthur, Jr.

Kansas Gas & Electric Co.
P.O. Box 204, Wichita, Kans. *H. W. Hobson*

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2480 E. 22d St., Cleveland 15, Ohio *M. A. Eskins*

Kelse-Burnett Electric Co.
223 W. Jackson Blvd., Chicago 6, Ill.
Sigmund A. Hollinger

Kerrigan Iron Works, Inc.
1055 Herman St., Nashville,Tenn. *G. E. Daniels*

Keystone Electric Manufacturing Co.
2228-36 E. Tioga St., Philadelphia 34, Pa.
Leonard M. Siegel

The Kirlin Company
3455 E. Jefferson Ave., Detroit 7, Mich.
Ivan Kirlin

Kopp Glass, Inc.
Swissvale, Pa. *F. C. Ashe*

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Richard C. Piper, Jr.

Leader Electric Manufacturing Corp.
3500 N. Kedzie St., Chicago 18, Ill. *Walter Glass*

The Leeds & Northrup Co.
4901 Stenton Ave., Philadelphia 44, Pa.
I. M. Stein

Libbey-Owens-Ford Glass Co., Plaskon Division
2112-24 Sylvan Ave., Toledo, Ohio
Dr. M. H. Bigelow

Light Control Company
3217 Casitas Ave., Los Angeles 26, Calif.
Stanley E. Lindahl

Lighting & Lamps
114 East 32d St., New York 16, N. Y.
James Krieger

Lighting Products, Inc.
2259 W. Park Ave., Highland Park, Ill.
D. E. Dunne

Lightolier Co.
11 East 36th St., New York 16, N. Y. *H. Stollnitz*

Line Material Co., Division of McGraw Electric Co.
800 North 8th St., Milwaukee 1, Wis. *M. C. Harsh*

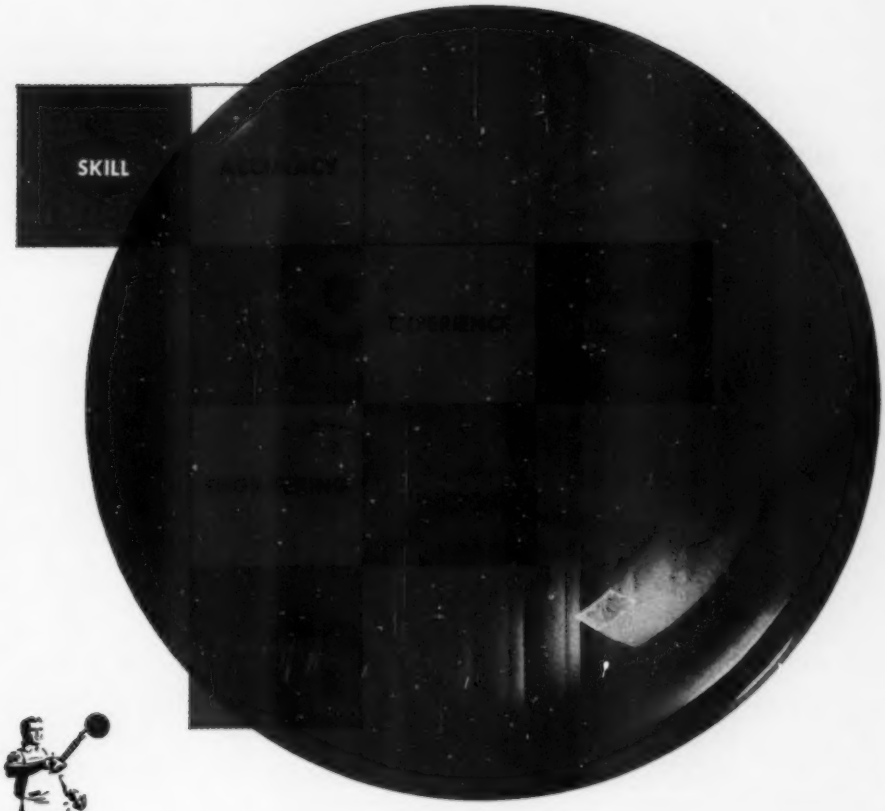
Litecontrol Corp.
36 Pleasant St., Watertown 72, Mass.
Paul H. Lamson

Lithonia Lighting Products Co., Inc.
Lithonia, Georgia *Robert J. Freeman*

Louisiana Power & Light Co.
142 Delaronde St., Station "A," New Orleans, La.
C. L. Osterberger

Luminator, Inc.
120 N. Peoria St., Chicago 7, Ill.
Albert L. Arenberg

(Continued on page 19A)



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Skill and experience are combined in both the design and manufacture of Kopp lenses, to assure complete fulfillment of your specifications. Because Kopp specializes in lighting glassware, employing modern laboratory research and highly developed manufacturing skills, you can have full confidence that Kopp lenses will give you the results you want.

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BY demonstrating the benefits of Light-Conditioning—the right lamps in the right fixtures in the right locations, General Electric is helping people everywhere get the most out of their lighting. For information on how you can tie into the Light-Conditioning program, write Lamp Department, General Electric Company, Div. 166-IE4, Nela Park, Cleveland 12, O.

(*Continued from page 16A*)

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90 Exchange St., Lynn, Mass. *James A. Cook*

Macbeth Corp.
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Malden Electric Co.
157 Pleasant St., Malden, Mass. *Donald S. Bennett*

Markel Electric Products, Inc.
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Morris L. Markel

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Nathan Bloom

Metal Window Institute
Cheltenham, Pa. *George Hingston*

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T. O. McQuiston

Metropolitan Electrical Supply Co.
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15th & Gentry Sts., No.Kansas City 16, Mo.
Sidney Lefkovitz

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Meriden, Conn. *G. W. Beals*

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Mississippi Power Co.
Gulfport, Miss. *R. M. Shearer*

Mississippi Power & Light Co.
Lampton Building, Jackson, Miss. *Les Taylor*

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Maplewood 17, Mo. *J. E. Baker*

Modern Light & Equip. Co.
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M. L. Offenberg

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1415 Illinois Ave., Sheboygan, Wis. *M. B. Deutsch*

Moe Light, Inc.
700 Oak St., Fort Atkinson, Wis. *Stanley Warner*

Montana-Dakota Utilities Co.
831 Second Ave. So., Minneapolis 2, Minn.
W. L. Hayes

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City of Pasadena, California, 302 City Hall,
Pasadena 1, Calif. *E. L. Bettannier*

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540 Empire State Bldg., New York 1, N. Y.
Morris Thau

The Narragansett Electric Co.
49 Westminster St., Providence 1, R. I.
C. R. Broadhead

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Luminall Paint Div.
3617 So. May St., Chicago 9, Ill.
John Marshall Ziv

National Lighting Products
4221 W. Harrison St., Chicago 24, Ill. *D. J. Epp*

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81 Prospect St., Brooklyn, N. Y. *M. J. Tombacher*

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693 Purchase St., New Bedford, Mass.
W. S. Fenstermacher

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317 Baronne St., New Orleans, La. *S. L. Drumm*

Niagara Mohawk Power Corp.
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Leland D. McCormac

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1620 Notre Dame St., West, Montreal, Quebec
F. P. Labey

Northern Indiana Public Service Co.
5265 Hohman Ave., Hammond, Ind.
J. C. Sackman

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Northern States Power Co.
Minneapolis 2, Minn. *Carl T. Bremicker*

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Akron 8, Ohio *C. L. Dunn*

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C. B. Morin

The Ohio Public Service Co.
P.O. Box 6058, Cleveland 1, Ohio *C. L. Dunn*

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Omaha Public Power District
720 Electric Bldg., Omaha 2, Nebraska
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Alfred A. Overbagh

Pacific Gas & Electric Co.
245 Market St., San Francisco 5, Calif. *O. R. Doerr*

Pacific Power & Light Co.
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C. A. Root

Peerless Electric Ltd.
1090 Pratt Ave., Outremont, Quebec
L. A. Van Duzer

Pennsylvania Electric Co.
535 Vine St., Johnstown, Pa. *Frank R. Knowles*

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P. G. Dingledy

Pennsylvania Power & Light Co.
901 Hamilton St., Allentown, Pa. *J. M. Stedman*

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H. B. Bryans

Philadelphia Electrical & Mfg. Co.
1200-36 N. 31st St., Philadelphia 21, Pa.
R. A. Manwaring

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Pierce Electric Co.
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Robert W. McKinley

Pittsburgh Plate Glass Co.
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Electric Bldg., Portland 5, Ore. *T. W. Fitch*

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Frank McLaughlin

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Dwight E. Worrell

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107 Craig St., West, Montreal, Que.
Paul E. Poitras

Quebec Power Co.
229 St. Joseph St., Quebec, Que.
Jean Saint-Jacques

Rambusch Decorating Co.
40 W. 13th St., New York 11, N. Y.
Edward Rambusch

Revere Electric Mfg. Co.
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Van N. Marker

Revere Electric Supply Co.
757 West Jackson Blvd., Chicago, Ill.
Floyd Ferneau

Rochester Gas & Electric Corp.
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Nyack, N. Y. *D. S. Schaab*

Rohm and Haas Co.
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Ruby-Philite Corp.
32-02 Queens Blvd., Long Island City 1, N. Y.
Louis Phillips

Rumsey Electric Co.
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Ryall Electric Supply Co.
1160 Stout, Denver, Colo. *C. O. Ryall*

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5050 Foster Ave., Chicago, Ill. *Cortes N. Sprankle*

Sandel Manufacturing Co.
3618 So. Loomis Place, Chicago 9, Ill. *A. L. Sandel*

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A. E. Holloway

Savannah Electric & Power Co.
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Carl Schranz, Jr.

Schomer Electric Supply
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Shawinigan Water and Power Co.
600 Dorchester St., W., Montreal, Que.
J. K. Wilson

The Sherwin-Williams Co.
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J. M. Gilbert

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A. L. Smith Iron Company
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Hugh M. Nazor

Smoot-Holman Co.
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L. A. Hobbs

Sola Electric Co.
4633 W. 16th St., Chicago 50, Ill. *L. C. Marschall*

Solar Light Mfg. Co.
1357 S. Jefferson St., Chicago 7, Ill. *A. Lazerson*

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Leon Beauchamp

Southern Calif. Edison Co., Ltd.
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Roy E. Dahlin

Southern Canada Power Co., Ltd.
355 James St., West, Montreal, Que.
George R. Atchinson

Southern Colorado Power Co.
Box 75, Pueblo, Colo. *E. H. Pemberton*

Southern Indiana Gas & Elec. Co.
P.O. Box 569, Evansville 3, Ind. *C. K. Graham*

Southern Lighting Mfg. Co.
P.O. Box 2546, Orlando, Fla. *Max K. Aulick*

Southwestern Gas & Elec. Co.
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Steber Manufacturing Co.
2700 Roosevelt Rd., Broadview, Maywood, Ill.
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Steiner Electric Co.
3500 Milwaukee Ave., Chicago 41, Ill.
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Public Service Bldg., Milwaukee 1, Wis.
G. W. Van Derzee

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J. D. Howard

Wisconsin Public Service Corp.
Green Bay, Wis. *A. G. Bur*

Worcester County Electric Co.
11 Foster St., Worcester, Mass. *Fred E. Littlefield*

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Rubin, W. J., The Atlantic Illuminating Co., Inc., Baltimore, Md.
Associate Member:
Goldberg, E. H., Goldberg & Hamilton Inc., Baltimore 16, Md.

CAPITAL SECTION

Associate Member:
Jordan, J. A., General Electric Supply Corp., Richmond, Va.

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Misra, R. P., Cornell University, Ithaca, N. Y.
Rapoport, H. L., Cornell University, Ithaca, N. Y.

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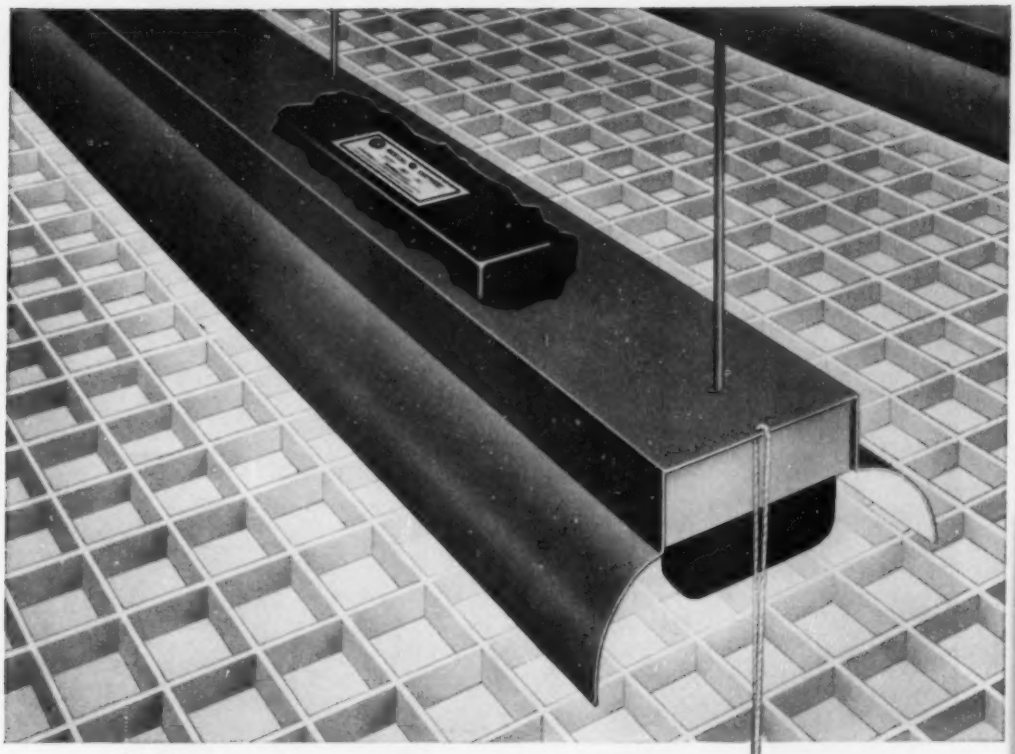
Goodwin, J. F., 624 S. Michigan Ave., Chicago, Ill.
Associate Members:
Holtzinger, J. R., Rambusch Decorating Co., New York, N. Y.
Hook, B. A. General Electric Co., Chicago, Ill.

(Continued on page 29A)



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ON LAMP PERFORMANCE?

For peak lamp performance, your "inside story" should begin with General Electric ballasts.

The ballast is the heart of the fluorescent fixture—it governs lamp performance. It's all-important in getting the level of light you want—and that's a job that can't be done by cutting corners in either design or manufacture, or by building to no more than the accepted standards of quality.

You gain by insisting upon General Electric ballasts because G-E ballasts are built to *exceed* accepted standards. With G-E ballasts in your fluorescent fixtures, you get proved dependability, extra lamp performance, and more light for your money.

Buy when you see the tag that says, "Equipped with a General Electric Ballast". That's the "tagline" to your inside story.

General Electric Co., Schenectady 5, N. Y.

GENERAL ELECTRIC

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Lighting by Litecontrol makes this

a Store with $ales Vision

TRENCH VARIETY STORE, MINNEAPOLIS, MINN.
Lighting Consultant: James McCracken, Northern States Power Co. Contractor: Heights Electric Co., Minneapolis. Fixtures: Litecontrol No. 5828, 8 ft. Slimline Louvered Troffers. Spacing: 8 ft. on centers. Watts per sq. ft., 2.08. Average intensity in service: 35 footcandles.

This Trench Variety Store in Minneapolis emphasizes modern merchandising from street entrance to storeroom. Clean lines and functional space-saving keynote the layout — . . . and, of course . . . *an excellent lighting job "wraps up the package."*

Sales-minded planning here dictated the use of Litecontrol Fixtures . . . in this case, the increasingly popular No. 5828 Slimline Recessed Louvered Units. Made for two or three lamps, this unit offers the convenience of hinged egg-crate louvers. Louvers are enclosed in metal frame for safety and are opened from either side by means of spring-loaded catches. Easy to service and easy on the eyes, Litecontrol Fixtures are justly famed for putting *every* product in the best possible light.

For lighting installations of this or any type, you'll save time and trouble by letting your Litecontrol Representative help you with your problem. Try him next time . . . and *see!*

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Lamp Division (H)
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STREET.....

CITY.....ZONE.....STATE.....

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per watt

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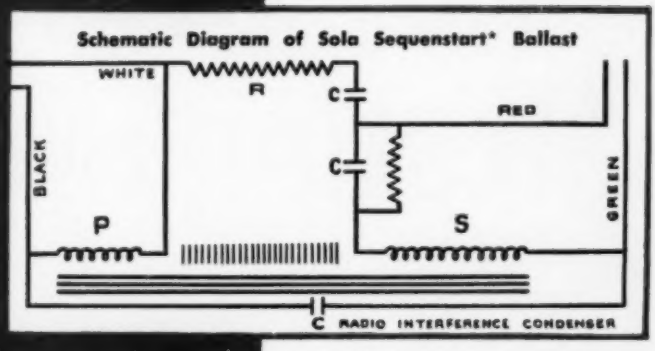
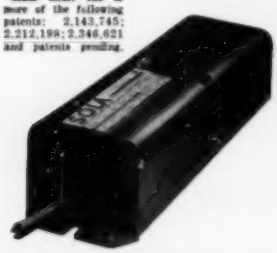


*Made under one or more of the following patents: 2,143,745; 2,212,198; 2,346,621 and patents pending.



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These publications summarize the studies and conclusions of technical committees of the Illuminating Engineering Society over a period of years. They contain the latest available information about many aspects of the art and science of illumination and include details of application as well as lighting technique. Each publication listed here carries the authority and approval of the Society.

These Society publications are available in single copies for information and for lighting reference book shelves or in quantity for educational or other distribution. Each publication is numbered for ordering when using the coupon printed on the back of this page.

(1) I.E.S. LIGHTING HANDBOOK

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I.E.S. APPROVED LIGHTING PRACTICES

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(3) OFFICE LIGHTING Recommended Practice (1947)

(4) STREET AND HIGHWAY LIGHTING American Standard Practice (1947)

(5) LIGHTING PRACTICES FOR STORES AND OTHER MERCHANDISING AREAS (1948)

(6) SCHOOL LIGHTING American Standard Practice (1946)

(7) LIBRARY LIGHTING Recommended Practice (1950)

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Close-up photos of visual tasks and levels and quality of illumination for roll, sifter and purifier floors; packing areas; and product control stations.

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*Originators of Moulded Plastic Louvers illustrated by . . .

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SPECIFICATIONS

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For 2, 3 or 4 Slimline lamps in 48", 72" or 96" length. One-piece louver of injection moulded plastic in choice of 31° or 45° shielding. Plastic is warp-proof, colorfast, "destaticized." Louver swings down to right or left for ease of servicing. Channel of 18 ga. steel. Curved translucent plastic side panels. Deep drawn end caps of 20 ga. steel, beautifully finished.

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Same specifications as above, but for 2, 3 or 4 40-watt lamps. Optional instant-start.

You'll find Leader's NHC Slimline fixtures installed wherever the demand is for the *finest* in fluorescent lighting—throughout the land in offices, schools, stores, all types of commercial establishments. These trim, slender, beautifully proportioned fixtures add distinction to any decorative effect. Feather-weight moulded plastic louver—*originated* by Leader—"sifts" light rays for pleasing, efficient diffusion. Precision engineering, beauty of appearance, economical performance and ease of servicing combine to make NHC the first choice when the demand is for the finest.

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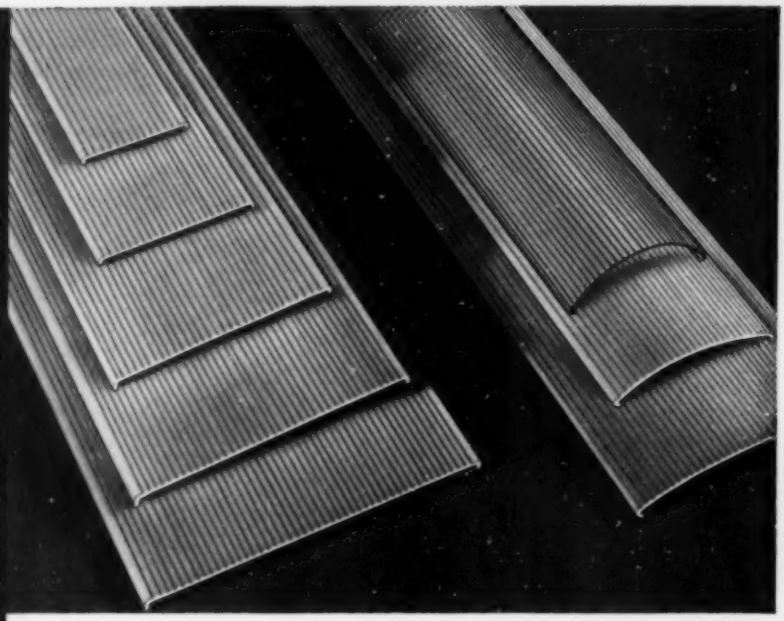

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WORLD'S LARGEST CUSTOM EXTRUDERS OF PLASTICS FOR ALL INDUSTRIES

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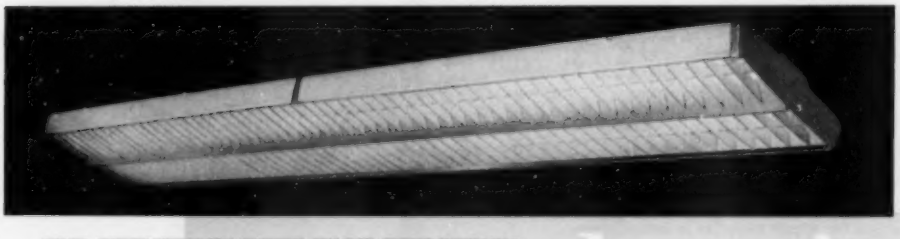
(*Continued on page 31A*)



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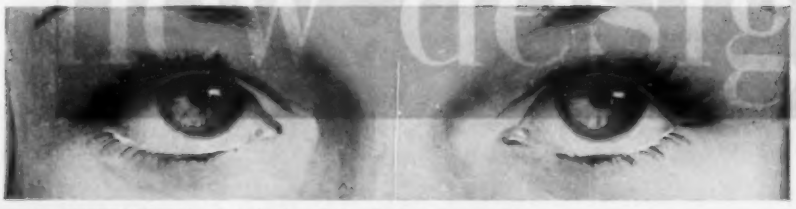

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These slimline lampholders, made of white urea, will accommodate T-6, T-8 and T-12 slimline lamps.

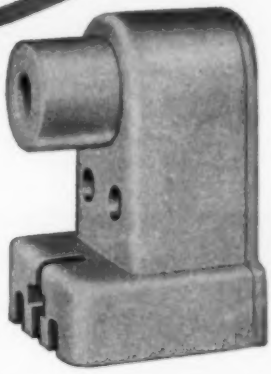
The terminals in both the high and low voltage lampholders are arranged to permit straight-in wiring . . . a most desirable feature.

The recessed binding screws are staked and backed out.

Spring-actuated plunger in the high voltage lampholder allows for ¼-inch variation in lamp length and ⅛-inch variation in lampholder mounting.

Single screw mounting with slot in front of base for No. 8 nut.

If surface mounting is desired, specify Nos. 4376-A and 4377-A which are equipped with terminal insulating covers. These covers are permanently hinged to the base and are readily snapped into a secure position after wiring.



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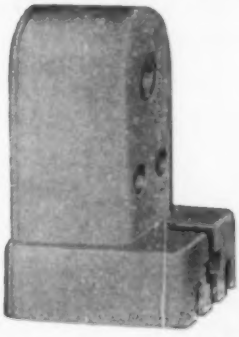
1000 Volts
(Flush Mounting)



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(*Continued from page 29A*)

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(*Continued on page 32A*)

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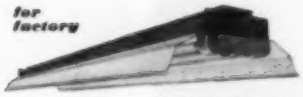

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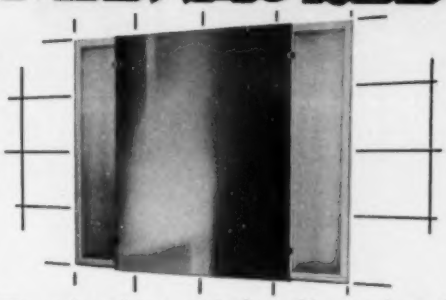

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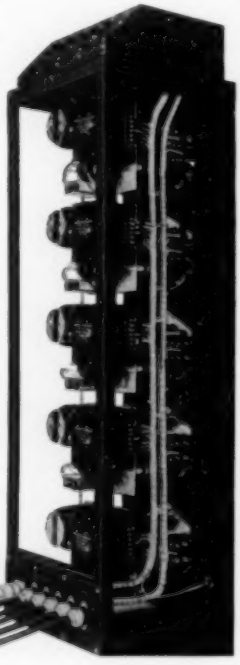

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Q What do the initials RLM stand for?

A The "R" stands for Reflector, the "L" for Lighting equipment and the "M" for Manufacturers—*Reflector* and *Lighting Equipment Manufacturers.*

Q What does the RLM Label stand for?

A The label affixed to a lighting unit certifies that the reflector meets the minimum specification and performance standards, determined and established by the RLM Standards Institute.

Q Who sponsors the RLM Standards Institute?

A Incorporated as a non-profit organization, the Institute is sponsored by twenty manufacturers who voluntarily elect to manufacture industrial lighting equipment in accordance with RLM Standard Specifications.

Q How are RLM Standard Specifications established?

A The RLM Technical Committee, with the counsel of outstanding illuminating engineers, continuously reviews present specifications and suggests improvements and prepares new specifications. The Committee's recommendations then are reviewed by the Board of Trustees and finally submitted to the Institute Members for ratification. The adoption of new specifications requires approval by at least 80% of the membership.

Q How does the RLM Label assure conformance to RLM Standards?

A Representatives of the Electrical Testing Laboratories periodically visit the plants of all manufacturers participating in the RLM Specification-Certification Program. These ETL inspectors are authorized to take lighting units right off the assembly line or out of stock at random and make the required tests. They may also obtain test samples direct from distributors' stocks in order to check conformance to RLM minimum standards.

Q Who are the Electrical Testing Laboratories?

A Electrical Testing Laboratories, Inc., 2 East End Ave., New York 21, N. Y., is an independent testing organization which has conspicuously served industry for over 50 years. With this impartial and scientific organization rests the sole responsibility of determining whether or not an industrial lighting unit measures up to every individual quality standard that qualifies it to bear the RLM Label.

Q What are the 4 Basic Tests made by Electrical Testing Laboratories?

A (1) Quality of reflecting surface, (2) Reflection factor, (3) Shielding angle and reflector dimensions, and (4) Photometric test for light distribution and efficiency.

Q In addition to design and construction features that meet certain minimum standards, what else does the RLM Label assure the buyer?

A It provides the buyer with a warranty of uniform quality. In addition to the periodical inspections and tests made by the Electrical Testing Laboratories, the manufacturer warrants that every unit shipped by him meets the published specifications of the Institute.

Q How many different types and sizes of RLM Units are there?

A There are 18 basic types of RLM Units and 35 different sizes made by one or more of the 20 member-manufacturers. At present there is available a total of over 250 different makes and types of units which either bear the RLM Label or are on submittal for testing and certification at Electrical Testing Laboratories.

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